Go-Lab

Global Online Science Labs for Inquiry Learning at School

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Deliverable D2.3

The Go-Lab Inventory and Integration of Online Labs – Labs Offered by External Partners and Federations

Editor(s)	Panagiotis Zervas (CERTH) and Eleftheria Tsourlidaki (EA)
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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
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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
Panagiotis Zervas, Stelios Sergis, Charalampos Alifragkis, Demetrios Sampson	CERTH
Eleftheria Tsourlidaki, Sofoklis Sotiriou	EA
Internal Reviewers	
Evita Tasiopoulou, Teodora Ioan	EUN
Wissam Halimi	EPFL

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Executive Summary

This document is the outcome of the work done during the 3rd year of the project in task *"T2.2 - Organizing Online Labs for the Go-Lab Federation: from Small to Big Ideas of Science",* 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 with online labs the Go-Lab Inventory for year 3;
- the main characteristics of the online labs included in the repository (including quality, diversity, multilingualism);
- the work done to conclude the validation of the Go-Lab "Big Ideas of Science" set.
- the steps towards the establishment of a communication hub between users and lab the validation of the owners;
- the validation of the Inquiry Learning Spaces (ILSs) metadata model so as to further develop the federated ecosystem of online labs and educational resources (inquiry learning activities that are making use of an online lab – or a series of online labs) that is available to the users (namely science teachers) through an effective search mechanism;
- the extension of the Go-Lab taxonomy to cover the Technology and Engineering (T&E) subject domains.

Overall, the Go-Lab inventory currently includes **161 online labs** (the initial indicator was to have 45 online labs at the end of the project) out of which 13 were integrated during the 1st year of the project, 35 during the 2nd year and 113 during the 3rd year of the project.

Furthermore, the consortium continues its efforts to establish cooperation with additional similar efforts all over the world. The Phet Interactive Simulations, the Concord Consortium, the Amrita University and the Create lab of the New York University are examples of such collaboration. The validation workshops carried out based on the remarks of the reviewers (Big Ideas of Science, Inquiry Learning Spaces metadata model[1]) were validated with pilot users (namely, science teachers and teachers' trainers) in the framework of specific workshops and activities. The data were analysed and the results are presented. Overall, **159 potential users** were involved in the validation exercises. In particular, **99 users** participated in the validation of the metadata elements set for online labs and **60 users** were involved in the validation of the Go-Lab set on the "Big Ideas of Science".

[1] We should clarify that it is beyond the scope of the present deliverable to present and discuss technical features of the Inquiry Learning Spaces metadata (such as indexing, interoperability and data export formats). This is part of WP4 and WP5 deliverables.

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1 Introduction

1.1 Scope

The main goal of WP2 is to create a structured inventory of online labs for their further integration through the Go-Lab portal. The inventory has been populated (and continues to be populated) with online labs offered by the Go-Lab partners and with online labs offered by lab owners outside the Go-Lab consortium.

The initial methodology to organize these online labs was the aim of tasks *"T2.2 - Organizing Online Labs for the Go-Lab Federation: from Small to Big Ideas of Science"* and *"T2.3 – The Go-lab Inventory of Online Labs*" and it was described in deliverable "*D2.1 - The Go-Lab Inventory and Integration of Online Labs – Labs Offered by Large Scientific Organisations*" (Go-Lab Project – D2.1). A series of workshops was done so as to validate this initial methodology and make sure it meets the needs of the users. The results of these workshops along with the presentation of the updated methodology were presented in deliverable "*D2.2 - The Go-Lab Inventory and Integration of Online Labs – Labs Offered by Universities*" (Go-Lab Project – D2.2)

The main scope of this deliverable is to present the further extension of the Go-Lab inventory by adding more labs that mostly come from external lab owners and federations.

Like in the previous round of online labs' integration, on top of increasing the number of labs, special attention was paid to adding online labs of high quality that meet the needs of the school communities. In addition, the labs introduced in this third version of the inventory were also selected so as to extend the coverage of the curriculum in more STEM subject areas. In particular, during this year our focus was mainly chemistry and physics. According to our plan, the subjects of Astronomy, Geography and Mathematics will be our main focus in the coming year. Thus, by the end of the integration process we will have a balanced repository throughout all STEM subject domains.

In addition to the ongoing extension of the Go-Lab inventory, this deliverable aims to present the work done in the framework of WP2 as a follow up to reviewers' comments during the second review of the project. Thus, this document also presents:

- the process of further establishing the Go-Lab federation of online labs;
- the additional work done on validating the Go-Lab set of the "Big Ideas of Science". This work includes introducing and receiving feedback from teachers and teachers' trainers on the updated set as well as from various stakeholders around the world;
- the establishment of a communication hub between lab owners and users;
- the work done in validating the metadata elements for the Go-Lab Inquiry Learning Spaces with teachers, so as to ensure that these metadata elements are useful for them during the process of searching for activities in the repository.

1.2 Audience

This document targets the Go-Lab partners, so that they can be aware of: (a) the current status of the Go-Lab inventory and the online labs that are included until the end of the 3rd year of the project; (b) the results of the workshops performed for validating the Go-Lab set of the "Big Ideas of Science",(c) the mechanisms that can be used by lab owners, so as to be aware about the usage of their online labs by the Go-Lab Teacher's community, (c) the validated metadata schema for characterizing Inquiry Learning Spaces (ILSs) and (e) the extension of the Go-Lab taxonomy to include terms for characterizing online labs and ILSs related to the Technology and Engineering (T&E) subject domains

The results of this work will be of particular interest for (a) WP5 for populating and further developing the Go-Lab Repository and (b) WP7 in order to support the implementation of the large scale pilots.

2 Populating the Go-Lab Inventory (Year 3)

2.1 Continuous support of the Large Scale Pilots

As mentioned in the Go-Lab DoW, Part B, pp.10-11, and in the previous deliverable "D2.2 - The Go-Lab Inventory and Integration of Online Labs – Labs Offered by Universities" the project is implementing a three-stage deployment cycle for populating the Go-Lab Inventory with online labs. Following this approach, in the two previous years of the project the consortium integrated 48 in total online labs coming from project partners (Year 1) (Go-Lab Project – D2.1) and from universities (Year 2) (Go-Lab Project – D2.2). In this third year of the project, we followed the same approach and we proceeded with adding online labs that come from external lab owners and federations.

In the coming year, we expect that the Go-Lab repository will be used by at least another 500 schools in addition to those that have already been using it. In order to support the total number of schools and the increased demand we aimed to extend the repository so that it covers a wider range of subjects as well as a wider range of age ranges. In addition, we also based our search for new labs on the topics that we were aware that are most popular among registered schools based on the sample profiles of schools that WP7 has been receiving throughout year 3 (Go-Lab Project – D7.4).

Furthermore, one additional issue we tried to tackle was to offer online labs of a wider language range. However, retrieving high quality labs in different languages that meet the requirements' set has proved to be more challenging than expected. To this end, on top of searching for multilingual labs, WP2 also collaborated with WP5 so as to deliver a mechanism that will allow the translation of any lab added in the repository. Thus, the translation of the Go-Lab online labs is now available through the Go-Lab App Composer (more information can be found in deliverable D5.6 "Releases of the Go-Lab portal and App Composer – Final"). We believe that providing this service may greatly benefit both the users of Go-Lab, as well as the lab owners who have integrated their labs in the Go-Lab repository. On one hand, this service will potentially allow every online lab in our repository to be available in any language. Thus users may have the opportunity to use any given lab in their mother tongue should they wish so. One the other hand, providing the opportunity to translate labs is also beneficial to lab owners, as they will get access to translated versions of their lab and thus extend its use in many countries.

Additionally, in collaboration with WP4 and WP5 we continued conducting dissemination events focusing on lab owners we have tried to reach numerous lab owners using the affiliation protocol established in deliverable D2.2. Finally, in order to increase of teachers participants and in order to make sure that the teachers' needs are met, we have set up a form in the Go-Lab repository, though which teachers may propose labs to be added in the repository.

Figure 1. The option of proposing an online lab in the online labs section of the Go-Lab Repository.

2.2 Liaisons with External Lab Owners and Federations

During the 3rd year of the project, there were extensive written communications with lab owners, which are not part of the Go-Lab consortium, so as to collaborate with them and include their online labs to the Go-Lab inventory. Table 1, presents the external lab owners that were contacted, as well as the number of online labs that were provided by these lab owners to be included in the Go-lab inventory.

Table 1: Lab Owners and Federations contacted during Year 3

No.	Lab Owner/Federation	URL	# of online labs added to the Go-Lab Inventory
1	PhET Interactive Simulations	https://phet.colorado.edu/	44
2	The Concord Consortium	http://concord.org/	35
3	RemLabNet Team	http://www.remlabnet.eu/	11
4	CREATE Lab, New York University	http://create.nyu.edu/	7
5	The University of St. Andrews	http://www.st-andrews.ac.uk/	3
6	Orfeus Data Centre	http://www.orfeus-eu.org/	1
7	MIT Office of Educational Innovation & Technology	http://oeit.mit.edu/	1
8	Amrita University Online Labs	http://amrita.olabs.co.in/	1
Total Online Labs (offered by external Lab Owners and Federations)			**103**

As we can notice from the Table 1, there are eight (8) external lab owners that were liaised with Go-Lab project during the 3rd year of the project. Through this process, 103 online labs were added to the Go-Lab inventory. Moreover, this provided the Go-Lab teacher's community with the opportunity to have access via the Go-Lab Repository to wide range of online labs for their teaching activities during the large-scale pilots of the project

3 Analysis of the Go-Lab Inventory of Online Labs

During the 3rd year of the project, 118 online labs (see Annex C) 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 populated the Go-Lab Repository (http://www.golabz.eu/). Considering also the 43 online labs that were already included in the Go-Lab repository during the first two years of the project, this has resulted in ***161 online labs*** that are available via the Go-Lab Repository.

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 year 3 of the project. This analysis is based on the following metadata elements: (a) lab type, (b) age range, (c) subject domain, (d) Big Ideas, (e) language and (f) difficulty and interaction level. The process includes two main steps:

Step 1: Calculate Occurrence Frequency: we calculated the occurrence frequency of the metadata values in respect to each metadata element. Occurrence frequency provides information about the metadata values that are used more often against other values of each metadata element.

Step 2: Calculate the Entropy of the Metadata Values: we calculated the information entropy of each metadata value in order to determine the variety of information included in the metadata of the online labs. Entropy as a measurement of information contained in a message was proposed by Shannon (2001) and it denotes the variety of information included in this message. Small values denote small variety of the information included in the message. For example, if all the metadata values in the Go-Lab Repository have the field "Type" set as "Virtual Lab", a new instance with this field set to "Virtual Lab" carries little information, meaning that it does not help to distinguish this particular online lab from the rest. On the other hand, if a new online lab metadata record has the "Type" field set to "Remote Lab", it is highly possible (based on the online labs of the Go-Lab Repository) that this value helps to differentiate this new Online Lab from the others. The entropy values for the aforementioned metadata data elements have been calculated following the formula below, which has been proposed by Ochoa (2009):

$$Entropy\ (metadata\_field) = 1 - \frac{\log(times(value))}{\log(n)}$$

where: *times(value)* is the number of times that the vocabulary value is present in this metadata field in the educational metadata records of our sample and *n* is the total number of educational metadata records, namely 185 for the sample of online labs that has been collected. When times(value) is 0 (the value is not present in the repository), the Entropy is 1. On the other hand, if times(value) is equal to n (all the instances have the same value), the Entropy is 0.

In our analysis, we used Heat Maps (Ochoa, 2009), in order to visualize the entropy for each value of the metadata element. According to this visualization technique, every metadata value is represented by a colour of the range from green to red. Green colour is assigned to metadata values with high information entropy, yellow colour is assigned to metadata values with moderate information entropy and red colour is assigned to metadata values with low information entropy. Moreover, according to this technique, the metadata values of the highest information entropy are represented by a darker shade of the green colour in contrast with lower level of high information entropy values that are represented by a lighter shade of the green colour. The same pattern is followed by metadata values with moderate and low information entropy that are represented by the yellow and the red colour respectively.

3.1 Lab Type Element Analysis

As previously mentioned, the Go-lab Repository (at the end of year 3) includes 161 online labs. In respect to their type, 125 (78%) are Virtual Labs, 30 (19%) are Remote Labs and 6 (3%) are Data Sets (see Figure 2 and Table 2). Figure 2 presents also the growth of the different types of online labs included in the Go-Lab Repository from year 2 to year 3.

Virtual labs are dominant in the Go-Lab Repository. This can be explained by the fact that virtual labs are not very costly to implement and many of them currently available online. As a result, it was easier to find available virtual labs and populate the 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 aims to further increase the number of remote labs and data set analysis tools, so as to balance out the number of online labs of each different type.

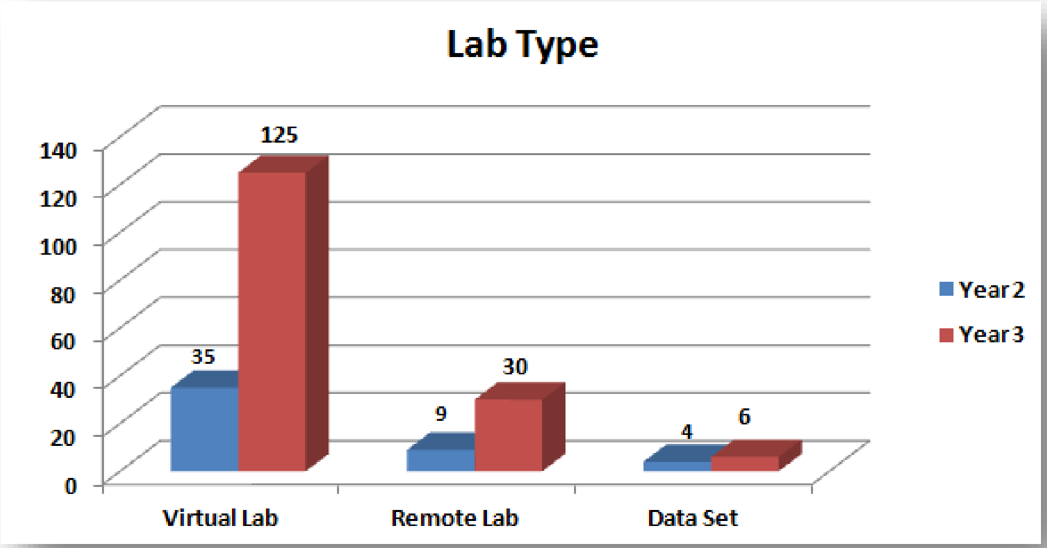


Figure 2: Occurrence Frequency of the Vocabulary Values of the Metadata Element "Lab Type".

Table 2: Heat map Table of the Entropy Values for the Vocabulary Values of the Metadata Element "Lab Type"

Lab Type	Entropy
Virtual lab	**0,049807221**
Remote lab	**0,330657996**
Data set	**0,647388922**

3.2 Age Range Element Analysis

The 161 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. However, there also adequate number of online labs that address primary education age ranges, namely 6-8, 8-10, 10-12 (see Figure 3 and

Table 3). Figure 3 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 2 and the online labs that are currently available in the Go-Lab Repository, namely end of year 3.

As a result, we can conclude that Go-Lab repository includes a balanced set of online labs in terms of addressed age ranges. However, the fourth year of the project, the project consortium aims to increase the number of online labs that address age ranges related to primary education namely 6-8, 8-10, 10-12.

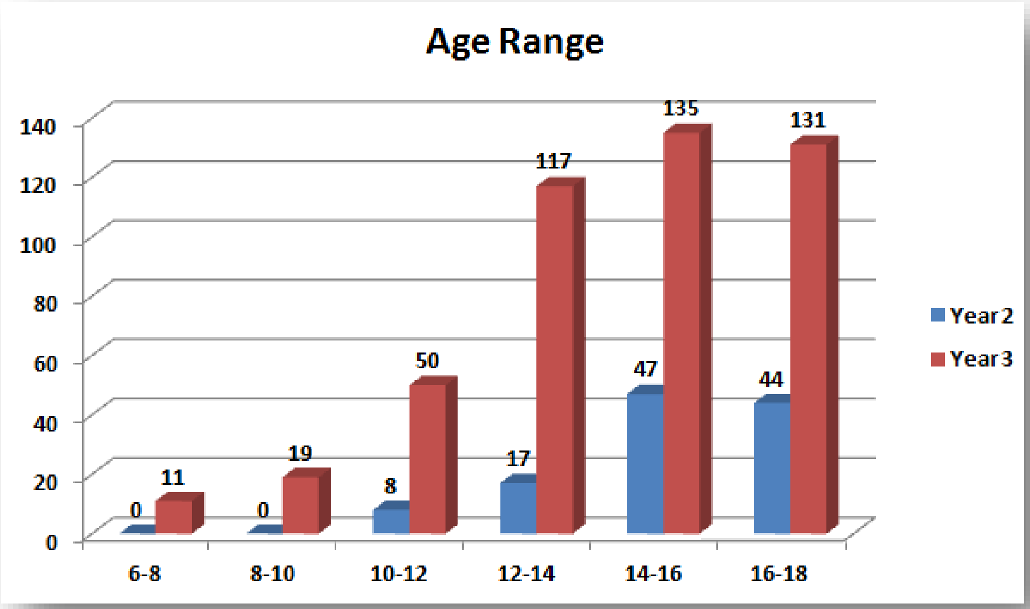


Figure 3: Occurrence Frequency of the Vocabulary Values of the Metadata Element “Age Range”.

Table 3: Heat map Table of the Entropy Values for the Vocabulary Values of the Metadata Element “Age Range”

Age Range	Entropy
14-16	0,213687156
16-18	0,218508555
12-14	0,236626142
10-12	0,372904868
8-10	0,528008054
6-8	0,615618709

3.3 Subject Domain Element Analysis

The 161 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, there are a limited number of online labs that focus on the subject domain of “Mathematics” (see Figure 4 and Table 4). Figure 4 presents also how the different subjects addressed by the online labs of the Go-Lab Repository have been increased from year 2 to year 3.

More specifically, the dominant sub-subject that is addressed by most online labs is Physics. This is explained by the fact the Physics includes many concepts that can be taught with the support online labs following the inquiry process.

Nevertheless, during the fourth year of the project, the project consortium aims to increase the number of online labs that address other sub-subjects of science education such as Environmental education, astronomy and geography and earth science. Moreover, the consortium will focus on adding online labs that address Mathematics, as well as Technology and Engineering aiming to cover the full spectrum of STEM School Education.

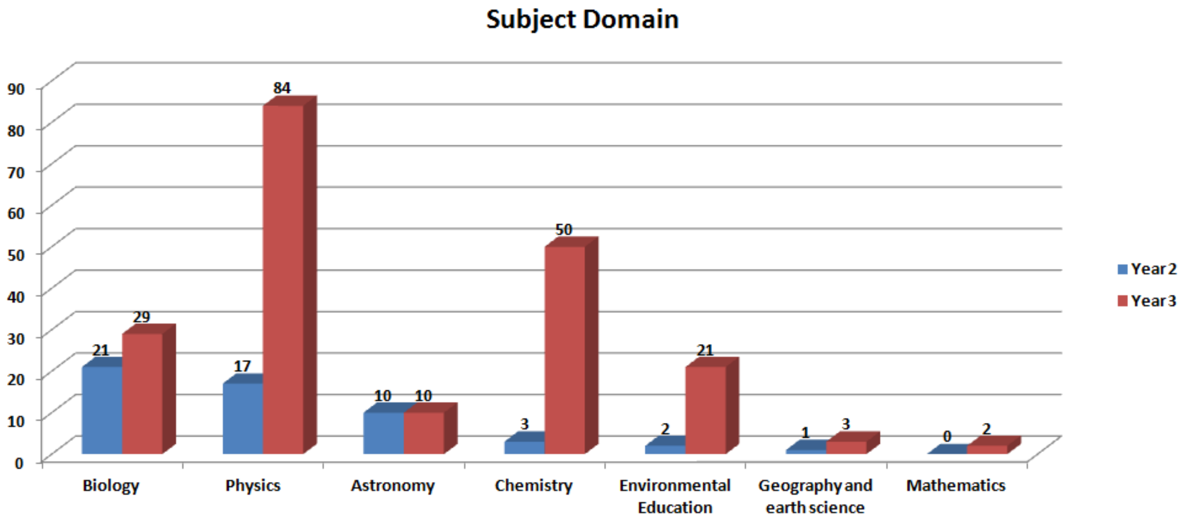


Figure 4: Occurrence Frequency of the Vocabulary Values of the Metadata Element “Subject Domain.

Table 4: Heat map Table of the Entropy Values for the Vocabulary Values of the Metadata Element "Subject Domain"

Subject Domain	Entropy
Physics	**0,162142007**
Chemistry	**0,260244806**
Biology	**0,363251551**
Environmental Education	**0,42428731**
Astronomy	**0,584509526**
Geography and earth science	**0,792254763**
Mathematics	**0,868927349**

3.4 Big Ideas Element Analysis

The 161 online labs of the Go-Lab Repository are addressing at least one of the 8 Big Ideas (Table 9) that are elaborated in Chapter 4. As we can see at the Figure 5 below, the most dominant Big Ideas that are addressed by the 161 online labs are Big Idea #2 (85 out of 161 online labs, 53%), Big Idea #4 (75 out of 161 online labs, 47%), and Big Idea #1 (54 out of 161 online labs, 34%). The Big Ideas #1 and #2 are most relevant to the subject domain of Physics which is the most dominant sub-subject that is being addressed by the 161 online labs (as described at Section 3.3 above). Similarly, the Big Idea #4 is most relevant to the subject domain of Chemistry which is the second dominant subject domain addressed by the online labs of the Go-Lab Repository.

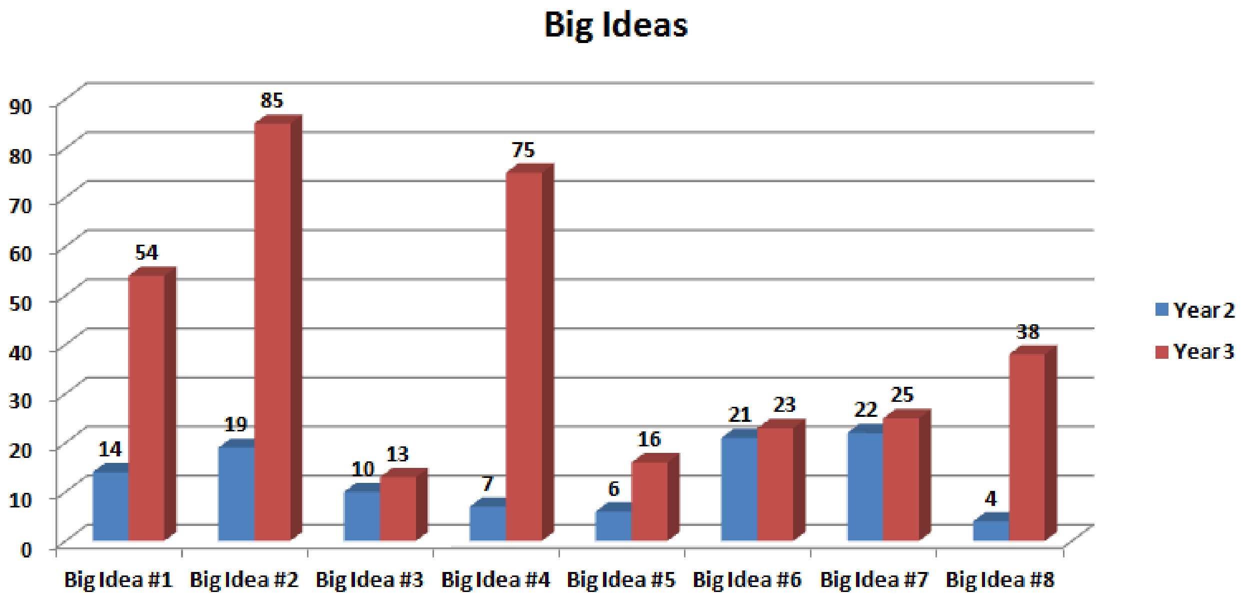


Figure 5: Occurrence Frequency of the Vocabulary Values of the Metadata Element "Subject Domain.

Table 5: Heat map Table of the Entropy Values for the Vocabulary Values of the Metadata Element "Big Ideas"

Distinct Data	Entropy
Big Idea #2 (*There are four fundamental interactions/ forces in nature*)	0,233505
Big Idea #4 (*All matter in the Universe is made of very small particles*)	0,255099
Big Idea #1 (*Energy cannot be created or destroyed*)	0,311776
Big Idea #8 (*Earth is a system of systems which influences and is influenced by life on the planet*)	0,372403
Big Idea #7 (*Organisms are organized on a cellular basis*)	0,444644
Big Idea #6 (*Evolution is the basis for both the unity of life and the biodiversity of organisms (living and extinct*)	0,45903
Big Idea #5 (*In very small scales our world is subjected to the laws of quantum mechanics*)	0,521642
Big Idea #3 (*Earth is a very small part of the universe*)	0,557467

3.5 *Multilingualism Element Analysis*

The 161 online labs of the GoLab 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 34 different languages that are supported by online labs included in the Go-Lab Repository. The most dominant language is English (159 out of 161 online labs, 98,7%) as depicted in Figure 6, thus we provide also a second level of analysis of the remaining languages in Figure 7.

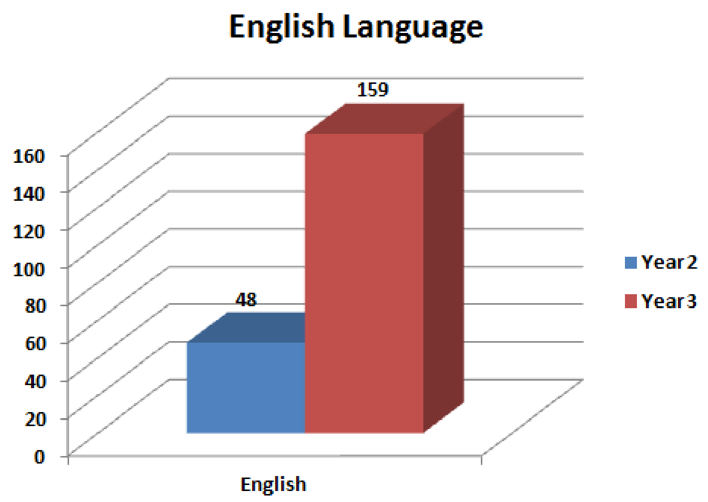


Figure 6: Occurrence Frequency of the Vocabulary Values of the Metadata Element "Language" for the Value "English".

Regarding the remaining languages, the dominant languages are: (a) Czech (16 out of 161 online labs, 10%), (b) Slovak (14 out of 161 online labs, 8,6%) and (c) German (13 out of the 161 online labs, 8,1%)

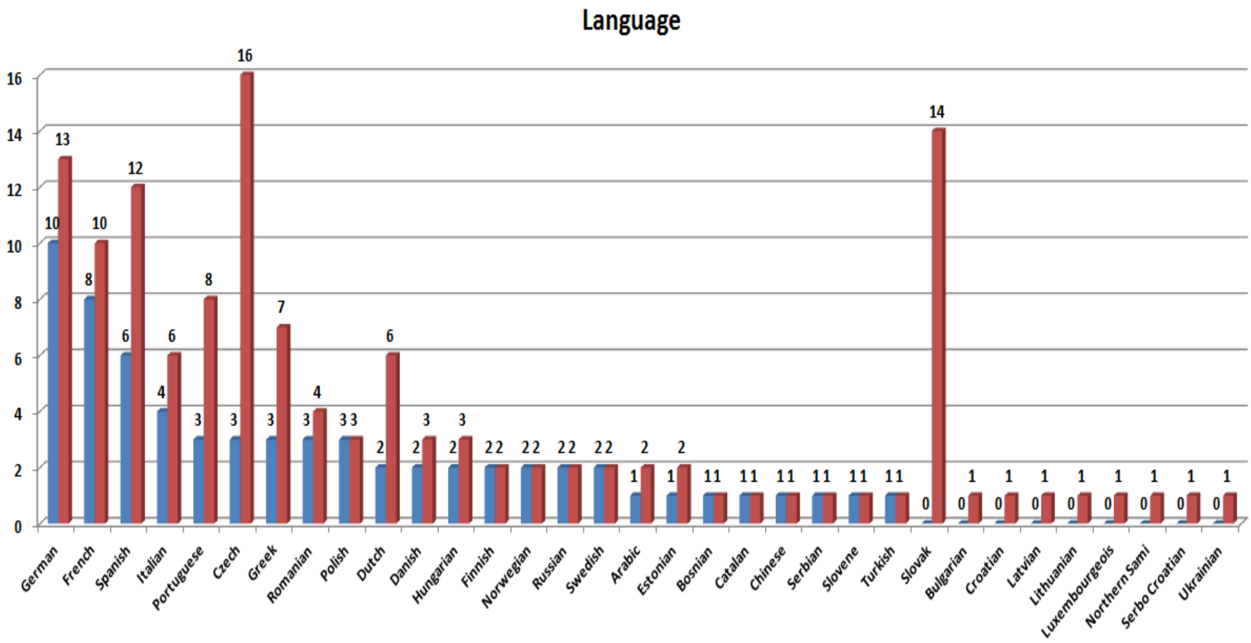


Figure 7: Occurrence Frequency of the Vocabulary Values of the Metadata Element "Language".

Table 6: Heat map Table of the Entropy Values for the Vocabulary Values of the Metadata Element “Language”

Distinct Data	Entropy
English	0,105995
Czech	0,510997
Slovak	0,534548
German	0,547618
Spanish	0,561736
French	0,593892
Portuguese	0,633248
Greek	0,656799
Dutch	0,683986
Italian	0,683986
Romanian	0,755499
Danish	0,806237
Hungarian	0,806237
Polish	0,806237
Arabic	0,877749
Estonian	0,877749
Finnish	0,877749
Norwegian	0,877749
Russian	0,877749
Swedish	0,877749
Bosnian	1
Catalan	1
Chinese	1
Serbian	1
Slovene	1
Turkish	1
Bulgarian	1
Croatian	1
Latvian	1
Lithuanian	1
Luxembourgish	1
Northern Sami	1
Serbo-Croatian	1
Ukrainian	1

3.6 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 the advanced difficulty level are limited (see Figure 8 and Table 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 challenging STEM concepts.

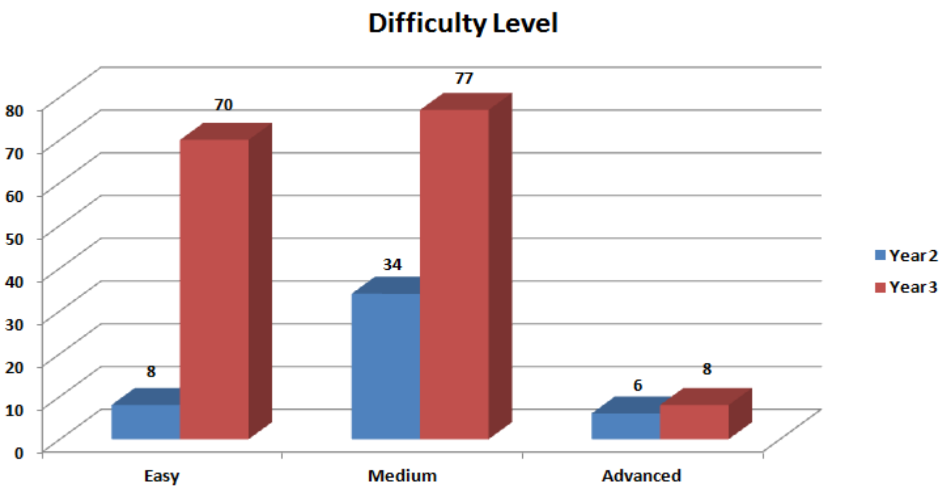


Figure 8: Occurrence Frequency of the Vocabulary Values of the Metadata Element "Level of Difficulty".

Table 7: Heat map Table of the Entropy Values for the Vocabulary Values of the Metadata Element "Level of Difficulty"

Difficulty Level	Entropy
Medium	**0,145156514**
Easy	**0,163913175**
Advanced	**0,590774244**

The dominant level of interaction of the online labs included in the Go-Lab repository is high, whereas there are a limited number of online labs with medium and low interaction level (see Figure 9 and Table 8). This means that most online labs in the Go-Lab repository require from the 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.

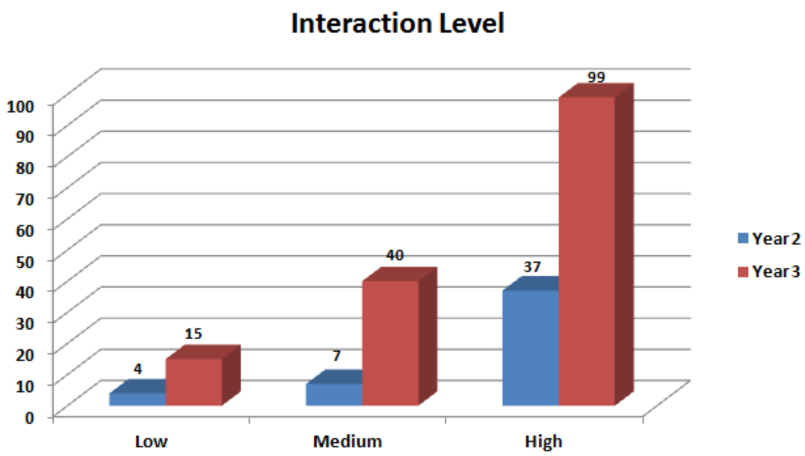


Figure 9: Occurrence Frequency of the Vocabulary Values of the Metadata Element "Level of Interaction".

Table 8: Heat map Table of the Entropy Values for the Vocabulary Values of the Metadata Element “Level of Interaction”

Interaction Level	Entropy
High	**0,095698842**
Medium	**0,274043318**
Low	**0,467066581**

4 The Go-Lab Set of “Big ideas of Science”

4.1. Continuation of validation workshops

The work done during year 3 on the validation of the “Big Ideas of Science” built upon the results and lessons learned during the validation workshops we carried out the year before. In order to be able to compare and aggregate results we followed the same research plan and methodology (presented in D2.2 - The Go-Lab Inventory and Integration of Online Labs – Labs Offered by Universities). What we changed in this year’s workshops was that instead of the original “Big Ideas of Science” set we used the updated one (also presented in D2.2, section 4.5) which is presented in table below:

Table 9: The updated Go-Lab Big Ideas of Science set

Modified Go-Lab set of Big Ideas
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. Energy can also turn into mass and vice versa.
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. Earth is a very small part of the universe. The Universe is comprised of billions of galaxies each of which contains billions of stars (suns) and other celestial objects. Earth is small part of a solar system with our Sun in its centre that in turn 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. Elementary particles as we know them so far form atoms and atoms form molecules. There is a finite number of types of atoms in the universe which are the elements of the periodic table.
5. In very small scales our world is subjected to the laws of quantum mechanics. All matter and radiation exhibit both wave and particle properties. We cannot simultaneously know the position and the momentum of a particle.
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. They require a supply of energy and materials. All life forms on our planet are based on this 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 influence the evolution of our planet, shapes its climate and surface. The solar system also influences Earth and life on the planet.

During this round of validation, we conducted another 8 additional workshops involving 135 more teachers and teachers’ trainer, thus reaching a total number of 19 workshops and 368 participants. In this year’s validation round we gathered 127 questionnaires out of the 135 workshop participants thus reaching in total 313 questionnaires. The overall results are presented below.

4.1.1. General information on the participants

Our workshops were conducted in Bulgaria, Cyprus, Greece, Portugal, the Netherlands and UK. As however 7 out of the 19 workshops were international (including the two Go-Lab summer schools), participants come from many more countries. The total sample of participants comes from Austria, Belgium, Bulgaria, Canada, Croatia, Cyprus, Estonia, Germany, Italy, Japan, Poland, Romania, Slovenia, South Africa, Spain, Switzerland, The Netherlands, UK and USA. The general characteristics of our sample are as follows:

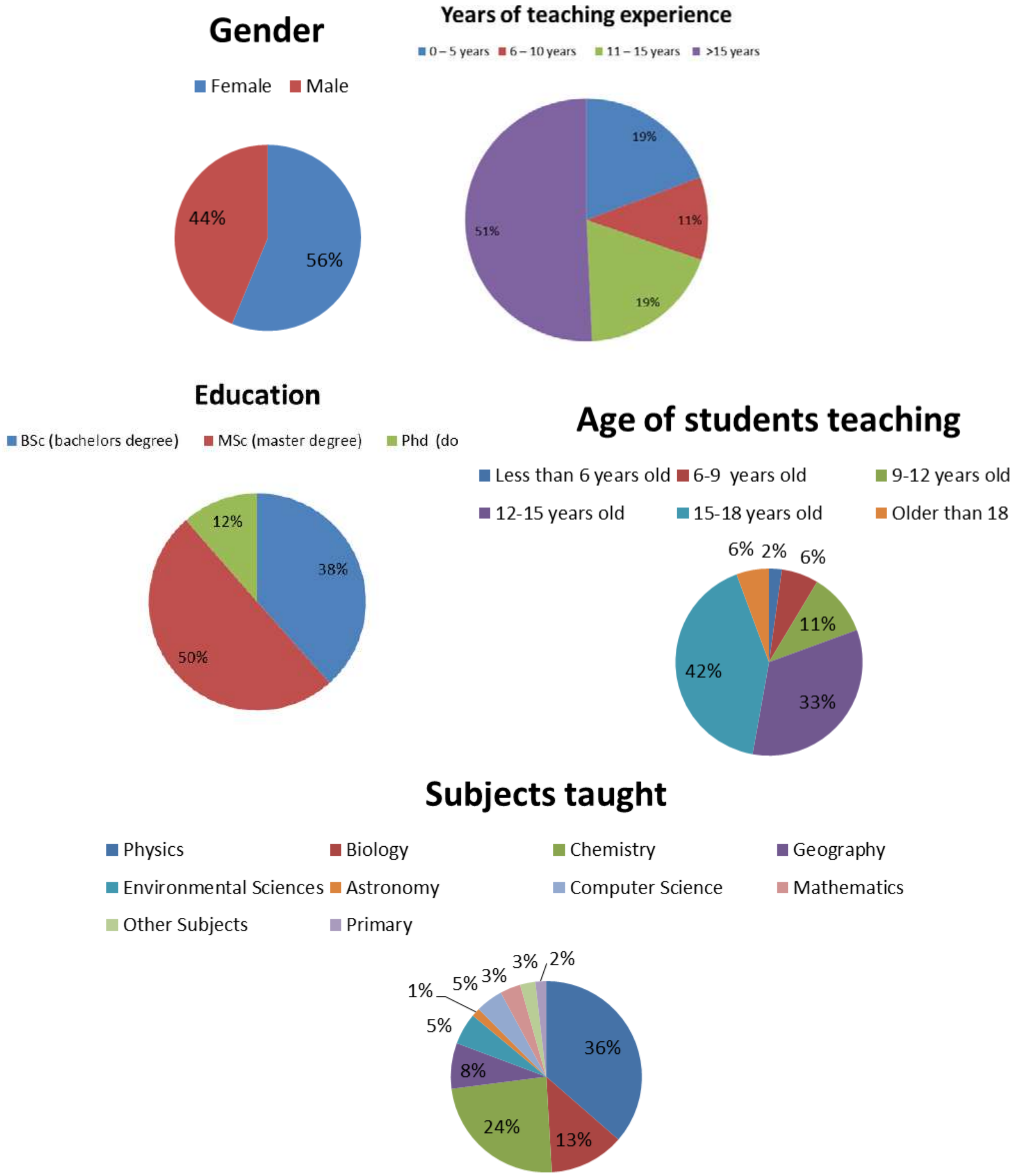


Figure 10: Profile of participants.

The target group for all our workshops was teachers who took part in the Go-Lab pilots over the first and the second pilot phase. As mentioned above, in total we reached a sample of 368 people in the 19 workshops that we carried out, out of which we have obtained and analyzed 313 questionnaires (85%). Based on the questionnaires we obtained, 59 people were teachers' trainers (19%) in their countries while the rest of them were mostly teachers of secondary education.

As for the general characteristics of our sample, based on the graphs presented above we can conclude that there is a gender balance between the participants (56% Female, 44% Male) and that the teachers' profiles are in accordance with the teachers expected to participate in the Go-Lab pilot phases as to their majority they teach mathematics, science subjects (92%) to students between 6 and 18 years old. In addition to this information, 50% of our sample has at least a master's degree and 70% has more than 11 years of teaching experience so they are considered to be quite experienced teachers.

4.1.2. Participants' familiarity with the concept "Big Ideas of Science"

During the workshops, we selected our data and information through two questionnaires as well as through discussions with the participants, just like in the workshops of the previous year. As mentioned above, the questionnaires used where not changed. Below, we present the results of our pre-workshop questionnaire for the total of our sample (313 questionnaires).

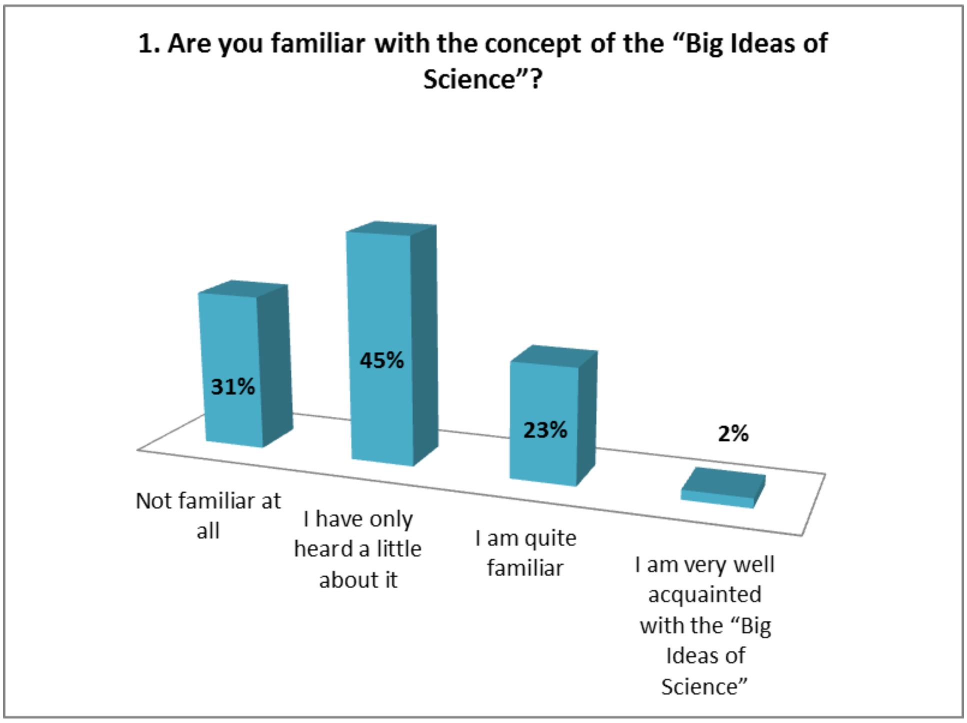


Figure 11: Participants' familiarity with the concept of the "Big Ideas of Science".

Table 10: Teachers opinion on the definition of the "Big Ideas of Science"

2. Which of the following definitions do you believe describes best the "Big Ideas of Science"?	Number of responses	Percentage
A. A set of ideas that briefly outline science's greatest achievements and discoveries.	43/313	14%
B. A set of cross-cutting scientific concepts that describe the world around us and allow us to conceive the connection between different natural phenomena.	**183/313**	**58%**
C. A set of concepts that outline how science works and what principles (ethical, social, economic and political implications) it is submitted to.	43/313	14%
D. A set of proposals that demonstrate to teachers how to teach science in the most successful and efficient way.	44/313	14%

As it can be seen from the results above, although the majority of participants have enough experience in teaching science (11% between 6 and 10 years of experience and 70% more than 11 years), 76% of them are basically not familiar with the concept of Big Ideas of Science, so we know they don't use this approach in their everyday teaching. However, despite the high percentage of people who are not familiar with Big Ideas of Science, 58% of them have selected definition number 2 which is the definition of Big Ideas of Science given in Go-Lab (Go-Lab deliverable D2.1, chapter 6, paragraph 6.1). This could indicate that although teachers are not very familiar with the term "Big Ideas of Science" it is still close to their understanding and they can quite easily relate to it and understand what it stands for.

In Go-Lab we aim to use the Big Ideas of Science in order to increase students' ability to make connections between different science concepts and phenomena from our everyday life. Thus, the four remaining questions of the pre-workshop questionnaire aim to record how often do teachers tend to connect what they teach their students to everyday life and to other science subjects respectively, as well as to identify to what degree the teachers believe that these connections are important to be made in the science class. The results are presented in the figures below.

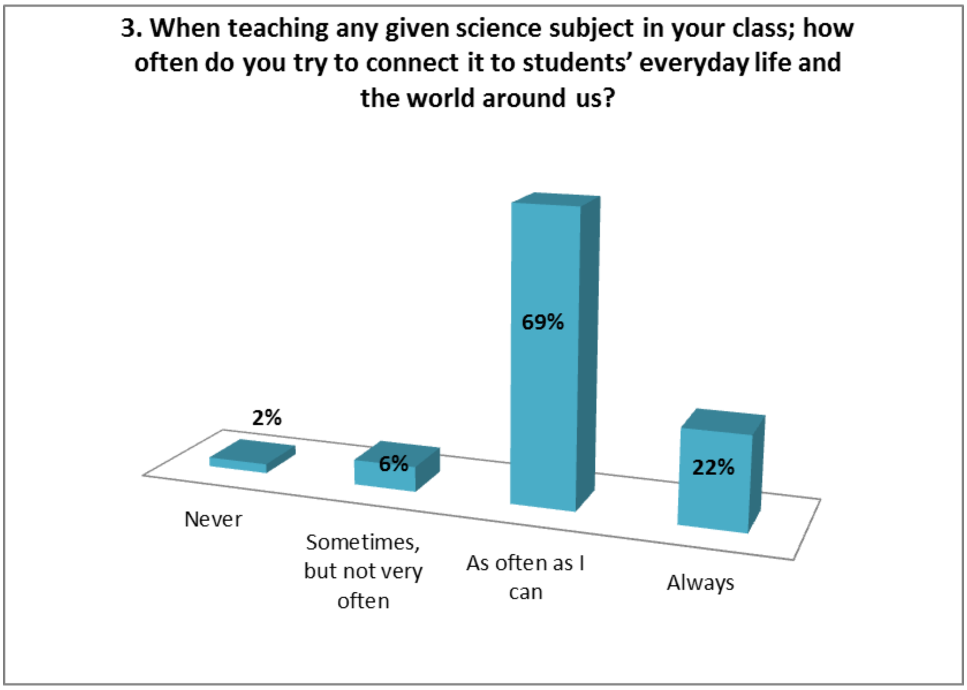


Figure 12: Participants' opinion on the frequency of connecting science subject domains with students' everyday life.

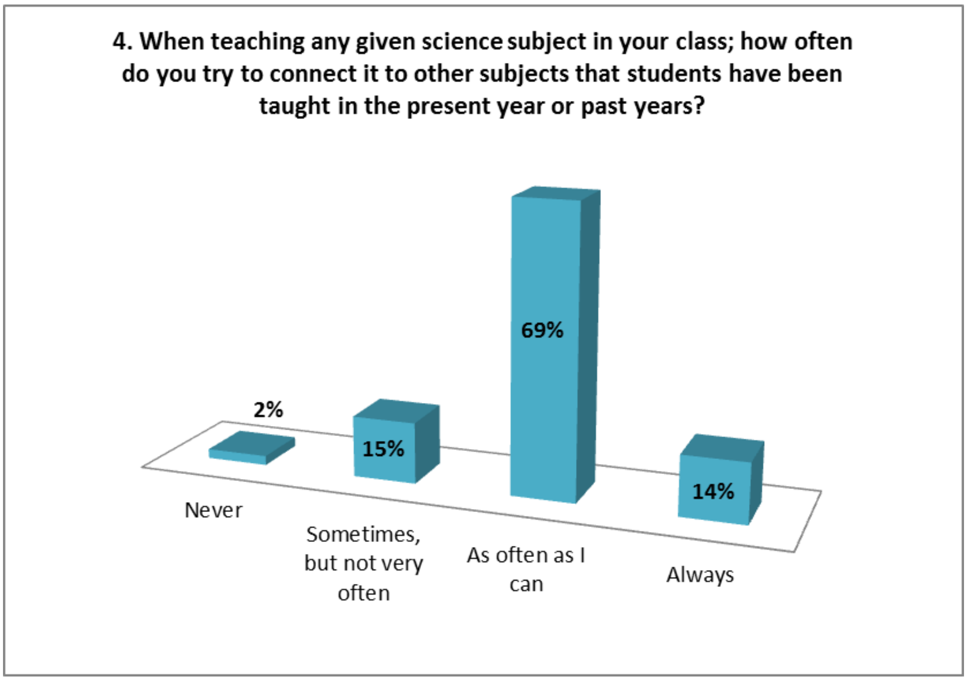


Figure 13: Participants' opinion on the frequency of connecting different science subject domains.

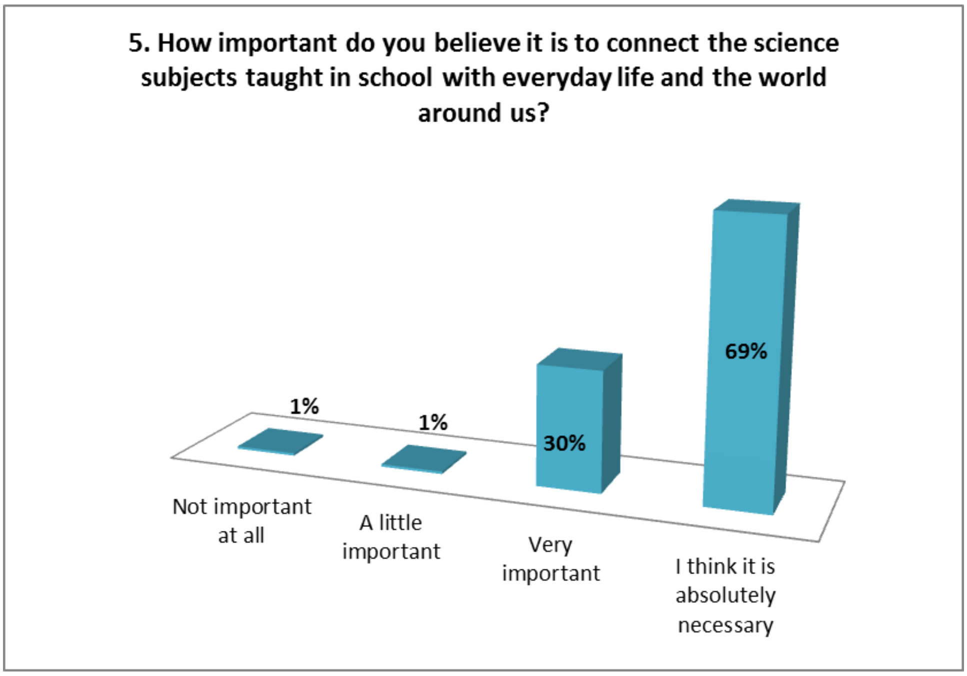


Figure 14: Participants' opinion on the importance of connecting science subject domains with students' everyday life.

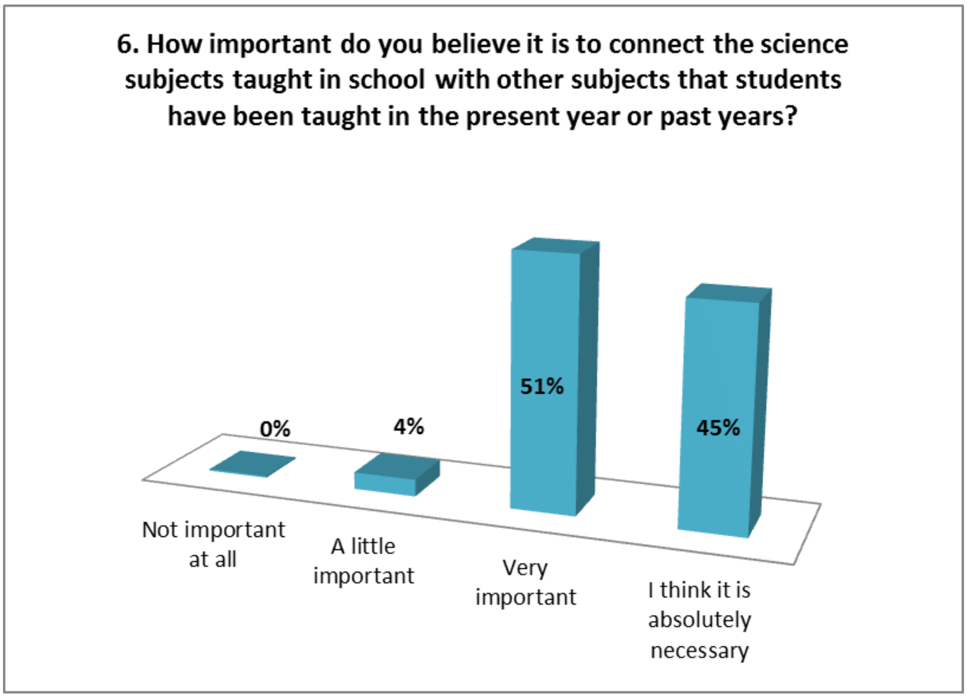


Figure 15: Participants' opinion on the importance of connecting different science subject domains.

As seen in the figures above, the connection between different science subjects and between science subjects and everyday life are of high importance for teachers. This is also evident by the fact that based on their answers they try to make such connections for their students as often as possible. Moreover, judging by figures 5 and 6, although both types of connections receive very high scores, between the two, teachers believe that the connection of what they teach at school to everyday life is more important as it scores more towards higher rating. This could also be an indication that teachers would prefer to teach more contemporary topics in their science class and introduce topics related to recent science discoveries.

Based on the fact that teachers have also stated that they are not familiar with the concept of Big Ideas of Science we can assume that they try to make these connections either using some other approach or in an uncoordinated way. In none of our workshops, did any participant mention anything about using a similar approach or another set of Big Ideas of Science.

The absence of a consistent framework that allows teachers to connect concepts and phenomena could also be an indication that students may understand the common ground between different phenomena and concepts in some cases but they do not have however a reference point to which they can go back and add build on as they move from one grade to the other.

Overall, teachers' answers and comments during discussions indicate that they are not provided with the means that will allow them to collaborate and be in position to work on making connections like those mentioned above. The Go-Lab set of Big Ideas of Science could play the role of such a backbone structure that the teachers can use in their class so as to communicate the matters under discussion in a more constructive way thus allowing students to build upon existing knowledge and experience.

4.1.3. What are the Big Ideas of Science according to teachers and teachers' trainers? – Comparison with the Go-Lab set of Big Ideas of Science

Just like in all previous workshops, there was a brainstorming phase during which teachers were asked to tell us what are the Big Ideas of Science according to their own understanding. Teachers would write their ideas on post-it notes and put them on a wall. After everyone had finished the teachers would cluster the post-it notes based on their similarity. Then they created groups, each of which was responsible for one cluster of post-it notes. Each group would have to come up with one Big Idea which would encompass all the small ideas that were written in the post-it notes. During the 8 workshops of year 3 we collected 538 additional small ideas which the teachers used to form their Big Ideas. Out of these, 505 (94%) were valid terms.

In order to categorize these terms, we used the classification made in the previous deliverable D2.2. In our analysis we studied all small ideas one by one so as to check if they are covered by one of the Big Ideas of Science in the Go-Lab set.

- **Basic elements and structure of matter:** (elements of the periodic table, bonds and reactions, elementary particles): 63 answers
- **Earth:** (climate, structure, phenomena, interaction with living organisms and ecosystems, atmosphere): 39 answers
- **Energy:** (conservation, transformation, forms, dark energy, connection to matter): 55 answers
- **Fundamental forces:** (gravity, electromagnetism, electricity, magnetism, motions, Newton's laws**,** interaction between objects, fields): 152 answers
- **Living organisms and evolution:** (cells, evolution, origin, biodiversity, DNA): 96 answers
- **Quantum mechanics:** 10 answers
- **Relativity Theory:** 3 answers

- **Universe:** (origin and evolution of the universe, scales, solar system, Earth's place in the universe): 39 answers
- **Time and Scales:** 5 answers
- **Universality of laws and principles, conservation of certain quantities in the universe:** 2 answers
- **Universe:** 23 answers
- **Waves:** (light, sound, wave-particle duality): 18 answers

We have found that all single small ideas are covered by the updated Go-Lab set with the exception of the 5 that refer to time and the scales of the universe. However, time and the scales of the universe are two concepts that are connected to every single one of the other concepts and instead of adding another Big Idea, it would make more sense to represent the current set of Big Ideas in the scales of time and space. Some additional comments about the small ideas under each category are presented below.

Table 11: Overall review on participants' answers covered by the current set

Category: Basic elements and structure of matter
Relative Go-Lab Big Ideas of Science: 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. Elementary particles as we know them so far form atoms and atoms form molecules. There is a finite number of types of atoms in the universe which are the elements of the periodic table.
Comments: Some answers included ideas about small particles in general and some others about the reactions between them. All of them are covered by the present idea.
Category: Earth
Relative Go-Lab Big Ideas of Science: Earth is a system of systems which influences and is influenced by life on the planet. The processes occurring within this system influence the evolution of our planet, shapes its climate and surface. The solar system also influences Earth and life on the planet.
Comments: Most answers refer to our environment and ecological systems. A few other refer to Earth in general. All answers are covered by the current Big Idea.
Category: Energy
Relative Go-Lab Big Ideas of Science: 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. Energy can also turn into mass and vice versa.
Comments: All answers refer to the conservation of energy which is covered by the current Big Idea.
Category: Fundamental forces
Relative Go-Lab Big Ideas of Science: 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.

Comments: Some answers refer to specific fundamental forces while some others refer to fundamental interactions in general. All answers are covered by the current Big Ideas of Science.
Category: Living organisms and evolution
Relative Go-Lab Big Ideas of Science: 1. 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. 2. Organisms are organized on a cellular basis. They require a supply of energy and materials. All life forms on our planet are based on this common key component.
Comments: Most answers refer to the evolution of life and genetic information. A few answers are concerned with specific procedures involved in evolution. All answers are cover by the two Go-Lab Big Ideas of Science.
Category: Universe
Relative Go-Lab Big Ideas of Science: Earth is a very small part of the universe. The Universe is comprised of billions of galaxies each of which contains billions of stars (suns) and other celestial objects. Earth is small part of a solar system with our Sun in its centre that in turn is a very small part of the Universe.
Comments: Some answers are about the solar system and some others are about the universe and our place in it. All these elements are included in our Big Idea of Science.
Category: Waves
Relative Go-Lab Big Ideas of Science: In very small scales our world is subjected to the laws of quantum mechanics. All matter and radiation exhibit both wave and particle properties. We cannot simultaneously know the position and the momentum of a particle.
Comments: Almost all answers in this category referred to light. A few referred to wave interactions. All answers are covered by the current Big Ideas of Science.

As mentioned above, teachers had to create clusters of small ideas based on the post-it notes they had written and then create a Big Idea of Science based on the small ideas of the cluster. Out of the 60 participants who worked in groups during the workshops, we obtained 16 Big Ideas of Science. These are presented below in comparison to our current Go-Lab set.

Table 12: Big Ideas of Science produced during the workshops compared to the Go-Lab set

Go-Lab set of Big Ideas	Big Ideas of Science produced by the participants.
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. Energy can also turn into mass and vice versa.	• Energy is a quantity in the universe that cannot be conversed. It can only be stored and transformed.
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.	• A force is an interaction with an object which can change its position and shape if unbalanced. There are 4 fundamental forces that can make an object unbalanced; electromagnetism, gravity and the strong and weak nuclear forces. • Electricity is a drive force of the modern world. It exists in energy household, every home. Electricity is power. Electricity is using electromagnetism. If there isn't electromagnetic polarity the earth will not spin. Electromagnetic effects every element from electrons to stars. • Gravity is the attraction to the Earth ground. The speed of gravity attraction depends on the weight of the object. The greater is the weight of the object the greater is the rate of gravity. The motion of the sea waves depends of the motion of the moon, which depends on the gravity. • There are 4 fundamental forces in the universe, and they are responsible for all interactions.
3. Earth is a very small part of the universe. The Universe is comprised of billions of galaxies each of which contains billions of stars (suns) and other celestial objects. Earth is small part of a solar system with our Sun in its centre that in turn is a very small part of the Universe.	• The universe is all around us, built from matter and energy. Our planet is a small dot around the Sun, one of the billion stars in our Milky way one of the billion galaxies in the universe all moving apart. • We live on a planet which is part of the solar system, which is part of a galaxy (the Milky way) which is 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. Elementary particles as we know them so far form atoms and atoms form molecules. There is a finite number of types of atoms in the universe which are the elements of the periodic table.	• All matter in the universe and around us is made of very small particles. The particles are in continuous motion. • Everything around us is matter/material which consists of small particles. They are interconnected between each other. • Matter has structural units that could be different at different scales (molecules, atoms and subatomic particles).

Go-Lab set of Big Ideas	Big Ideas of Science produced by the participants.
5. In very small scales our world is subjected to the laws of quantum mechanics. All matter and radiation exhibit both wave and particle properties. We cannot simultaneously know the position and the momentum of a particle.	• Quantum mechanics helps us explain the microcosm. • Light has strange properties. In some situations it will behave as a wave sometimes as a particle. It is a kind of electromagnetic interactions. Nothing travels faster than light.
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.	• Life is an ongoing evolving process. It started in the oceans and it is evolving through sexual selection and affected by the environment. • The cells and DNA are the basic biological unity of all life on Earth
7. Organisms are organized on a cellular basis. They require a supply of energy and materials. All life forms on our planet are based on this common key component.	• All living organisms are made of cells and the cell is the structure where all life processes take place. • All living organisms are constructed by cells. In order for them to exist they need energy. The energy is necessary for change and the series of changes is called evolution.
8. Earth is a system of systems which influences and is influenced by life on the planet. The processes occurring within this system influence the evolution of our planet, shapes its climate and surface. The solar system also influences Earth and life on the planet.	• Systems are dynamic interactions between different parts or smaller systems. • The Earth rotates around its axis and around the Sun. In our world there are different natural systems which interact with one another and changes in one of them affect the others.

As it can be seen in the table above the Big Ideas of Science produced by the participants are quite close to the ones in the Go-Lab set. In some cases, like in Big Idea 2 participants chose to make separate ideas about each interaction. This was the case when small ideas of other interactions did not come up during the brainstorming session of that workshop. It is also worth noticing that in none of our workshops did the participants mention any ideas about quantum mechanics.

The next step of our analysis included the review of the answers given in question 4 (optional question). Out of the 127 questionnaires we obtained 47 comments which are presented below.

Table 13: Comments and suggestions by the participants on the Go-Lab “Big Ideas of Science” set

Comments

- 3 and 8 are connected to each other.
- A little bit too extra information. Too descriptive.
- At a first glance it looks complete.
- Has several points of dispute in definitions and accompanied text.
- I like it. It is simple and we can build on it.
- I think that set A has the fundamental big ideas.
- I think that set A has the fundamental ideas.
- It contains a compact sentence and also more 'in depth' description.
- No, but I believe it is more difficult to teach it to students.
- No, set A is quite analytical as it is.
- Nothing is redundant. It is more apt for use from older students and adults.
- Set A is a more complete description of some ideas from set B. There are no ideas about science and the nature of science.
- Set A is more complicated and includes terms which are probably not introduced to students' programme at school.
- Some ideas are very vague.
- The connection to other disciplines is missing.
- The set is well phrased. It corresponds to senior students' knowledge and not younger ones.
- The two sets are not so different.
- There are more information/specific inform.
- Too many facts in explanations.
- Don't know if something is missing. 8 is perhaps a bit less general than the others.
- Everything is a cycle around of 8 suggestions of set A.

Suggestions

- I would add a bit more information to every idea. To make the connections more clear.
- Big bang and evolution theory of the universe.
- Big ideas 2 and 5 can be put into a single idea.
- DNA, energy degradation, atomic theory.
- Energy and mass are two faces of the same coin.
- Evolution theory is missing.
- Evolution: miss idea of adaptation/change.
  Quantum mechanics: is a big debate. is it essential for people to understand the world?
- exoplanets could be in 3.
- Genetic engineering is missing. This is an important concept used in many cases in our life.
- I don't like point 8 because earth is a system of systems is too generic.
- I don't like the first point about energy. Some actual scientific investigations claims different ideas.
- I would probably omit item 5. Talk about nature of light rather than quantum mechanics.
- I would probably omit or adapt number 5. Talk about nature of light rather than quantum mechanics.
- Impact of nature to our life.
- It is missing something about animals and the way they live.
- It speaks about the transformation but not about the beginning (it existed before) and the end (but it will never be destroyed).
- Number 5 is redundant.

- Number 8 should mention ecosystems.
- Point 5 - How is written doesn't mean much, It's difficult to understand why students should know this.
- Point 6 - Evolution is the basis of diversity of life not life itself.
- Point 5 is not so important for me.
- The earth point is too focused in the size and position or movement. 3. Earth is not the center of the universe. 8. I would add fragile.
- The passing of genetic information from one generation to the other is missing.
- Would suggest re-wording of quantum to explain what/why it is important.

Based on the list above, the only comment that appears a few times is about the Big Idea regarding quantum mechanics. These comments question the importance of this idea and mention that it might be too difficult for students to understand. Indeed, quantum mechanics is a subject which is quite difficult for students to understand and it is completely absent from the curriculum of many countries. However, based on our understanding, quantum mechanics is fundamental when it comes to understanding the small scales of our universe and students need to have at least a brief idea of what quantum mechanics is by the time they leave school.

Just like in our previous workshops, another metric we used to assess the Go-Lab Big Ideas of Science was to ask participants to compare it with another one from the bibliography. The results are presented below in Figure 16 and Figure 17. It should be noted that the sets were presented to participants as “Set A” and “Set B” in order to avoid biased answers.

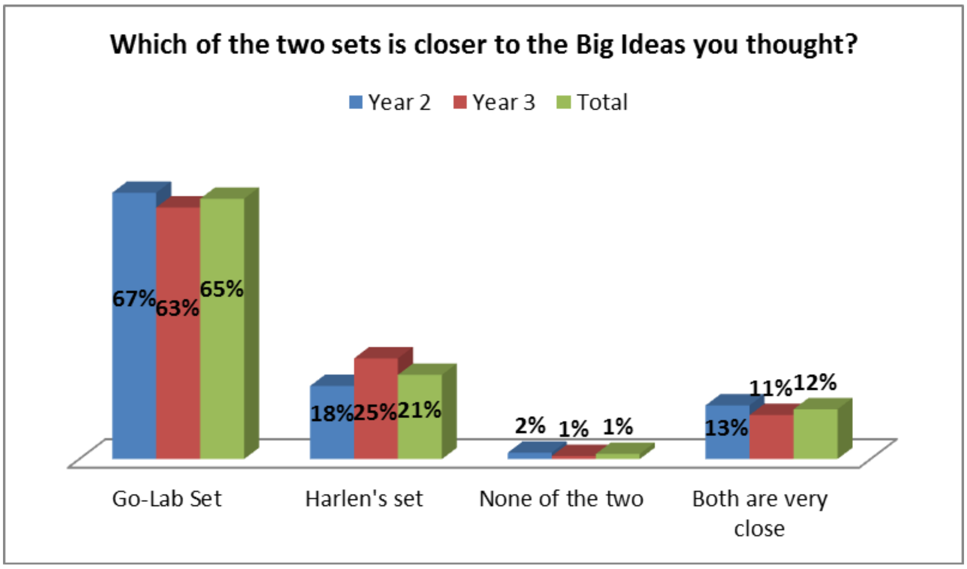


Figure 16: Comparison between Big Ideas of Science produced by participants, the Go-Lab set and Harlen's set of Big Ideas Of Science.

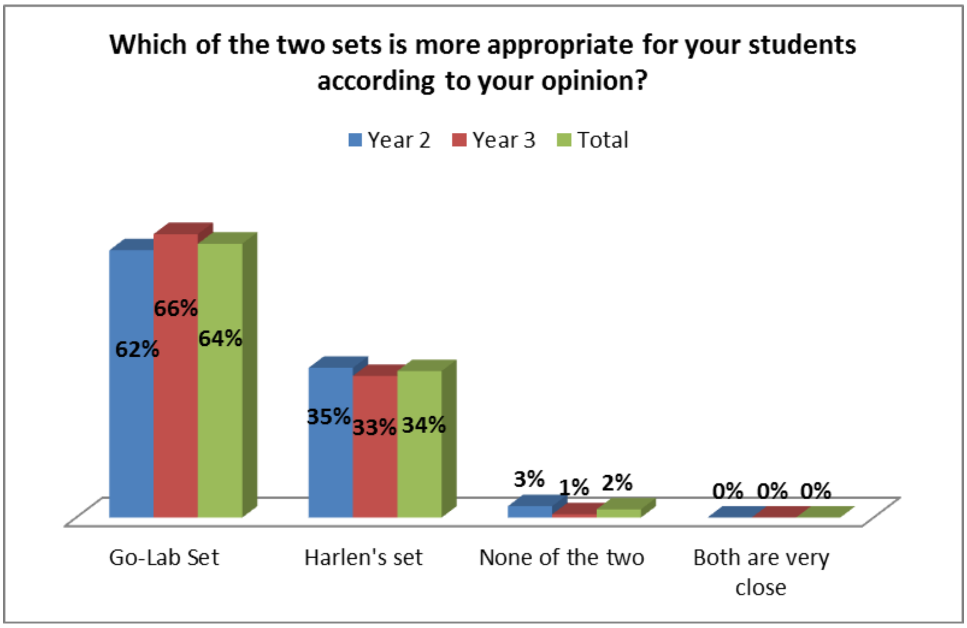


Figure 17: Participants' opinion on using Big Ideas of Science set in the class.

As seen in the figures above, in the workshops carried out in year 3, again the majority of teachers (63%) feel that their ideas were closer to the Go-Lab set. However the percentage is lower compared to the workshops carried out in Year 2 (67%). This could be due to the fact that the updated set of Big Ideas is even more descriptive than the original one. Thus, since teachers tend to make smaller phrases for their Big Ideas due to time restrictions during the workshop, this is a justified outcome.

On the other hand, in this second round, teachers seem to be even more strongly in favor of using the Go-Lab set in their classes (66%). Out of the 127 questionnaires, 98 also included an explanation why the participant chose one set over the other. Like in the previous round of workshops, the comments of teachers who selected the Go-Lab over Harlen's set (63 out of 98 comments) state that they did so because they find set A to be more detailed, complete and descriptive. Teachers' comments who selected Harlen's set (34 out of 98) indicated that these participants did so because they find Harlen's set to be easier to understand and more concise and simple for students.

The two following questions were about the degree to which participants found the Go-Lab set to be satisfying and how important do they believe the "Big Ideas of Science" are when it comes to teaching science. The results are presented below in Figure 18 and Figure 19.

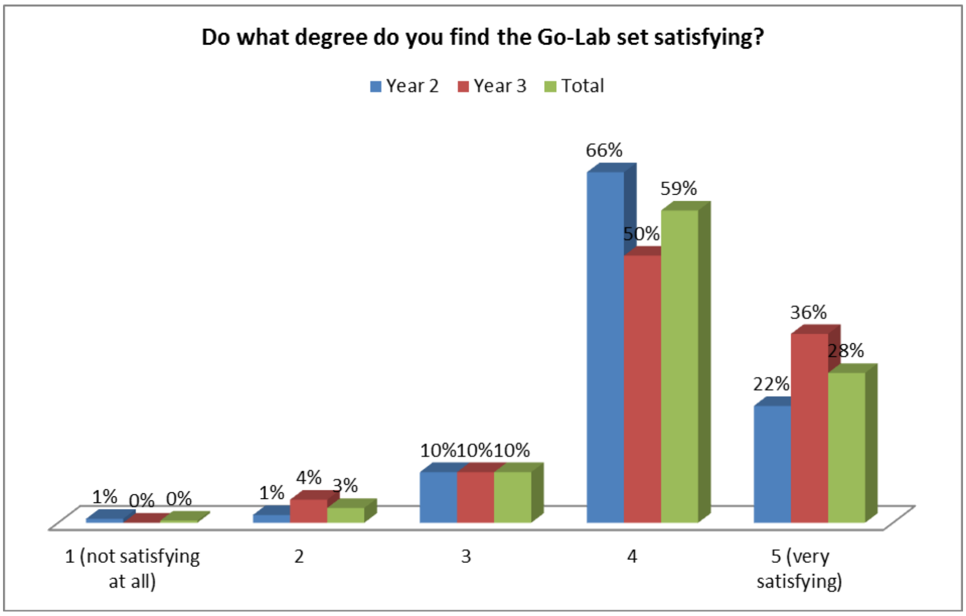


Figure 18: Participants opinion on the Go-Lab “Big Ideas of Science” set.

The results of the workshops during year 3 indicate that there is a shift in participants' opinion towards higher rating with regards to the degree to which they find the Go-Lab set satisfying. In year 2, 66% gave a score of 4 out of 5 and 22% gave 5 out of 5 (4.1 average rating). In year 3 the percentage giving score 4 out of 5 has decreased to 50% (11% drop) and at the same time the percentage of participants giving a score 5 out of 5 has increased to 36% (14% increase, 4.2 average score). This shift leads us to believe that the updated version of our Go-Lab set, which was done based on teachers and teachers' trainers recommendations from the previous workshops, is more appealing to teachers and suits their needs even better.

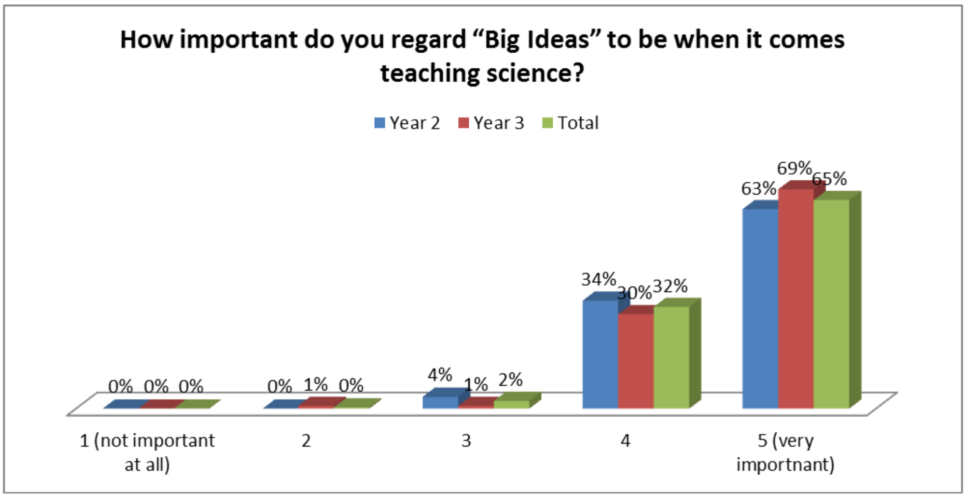


Figure 19: Participants' opinion on the importance of Big Ideas of Science related to teaching science.

Figure 19 indicates that 99% of our participants feel that the “Big Ideas of Science” are important or very important when it comes to teaching science. As the “Big Ideas of Science” are meant to be used as the means to connect different science subjects, it is worth comparing Figure 19 to Figure 15. The data presented in these two graphs concern very similar questions. By comparing the two figures we can see that, like in the workshops of year 2, there is a shift towards higher rating after the completion of the workshop. This could indicate that the workshop has strengthened teachers' opinion on the importance of connecting science subjects while teaching.

Teachers' opinion during workshops done in year 2, as seen in Figure 19, led us to add an additional question to the post questionnaire used during year 3 (Annex A2). Since teachers believe that the "Big Ideas of Science" is important in teaching science, what we wanted to further investigate was whether a recommendation system using the "Big Ideas of Science" would be helpful. The results of this question are presented below in Figure 20.

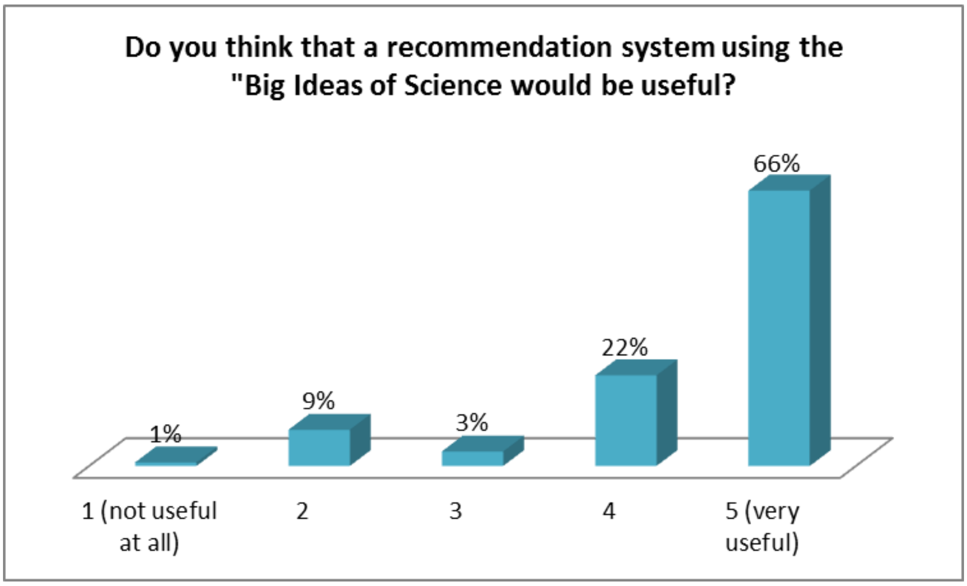


Figure 20: Participants' opinion on the usefulness of a "Big Ideas of Science" recommendation system.

As it can be seen in the figure above, the results are very positive, as 88% of the participants believe that such a recommendation system could be useful of very useful. Given these results we strongly believe that the presence of the "Big Ideas of Science" in the GoLabz repository can be very beneficial for teachers, especially if they are used as a recommendation system for online labs and Inquiry Learning Spaces. As the "Big Ideas of Science" are already incorporated in GoLabz, what remained to be investigated was if the current presentation is effective and if the teachers can easily use the "Big Ideas of Science" as a recommendation system in GoLabz. This investigation is presented in the following chapter.

4.1.4. Conclusions

In the third year of our project we continued our research on the "Big Ideas of Science" and their use in the Go-Lab portal. The workshops done in year 3 followed the same format as year 2 so as to be able to compare results. The main change in our investigation was that we switched to the updated Go-Lab "Big Ideas of Science" set. The updated set was the product of last year's research and of the feedback we got from participants. Evidence show that the updated version of the Go-Lab set had a greater impact on workshop participants, as they gave it a higher score then last year when asked to what degree they found it satisfying. In addition, contrary to last year, in this year's research we found no terms and ideas proposed by the participants that were not already covered by the existing set. Based on these two main results we concluded that no further changes were needed in the Go-Lab “Big Ideas of Science” set. Our results also indicated that teachers and teachers’ trainers believe that the “Big Ideas of Science” could play the role of a recommendation system. To this end we proceeded with investigating whether the current presentation of the “Big Ideas of Science” is effective and if it facilitates teachers in retrieving related labs and activities. The results of this investigation are presented below.

4.2. Teachers’ opinion on the presentation of the “Big Ideas of Science” in GoLabz and their use as a recommendation system.

In the three workshops we carried out on the “Big Ideas of Science”, during year 3, we also conducted an additional usability test. This usability test aimed to investigate whether the “Big Ideas of Science”, as they are presented in the Go-Lab repository can inform and direct the selection of labs by users. Thus what we set out to investigate with this usability test was whether the presentation of the “Big Ideas of Science” was clear enough for them so they can get easily be informed about what they are and what is their role in the repository as well as the degree to which the teachers could find labs that share the same “Big Ideas of Science” (thus direct their selection of labs through the “Big Ideas of Science”).

4.2.1. Usability test description

The test was carried out with each participant individually. Overall we gathered 57 tests from 60 participants (95%). The facilitator of the workshop and the participant sat down in front of a computer where a browser was displaying the Go-Lab repository. The participant navigated through the Go-Lab repository based on the questions asked by the facilitator (presented below). The facilitator noted down the participant’s actions and comments. The usability tests were carried out before the Go-Lab Big Ideas of Science were presented to the participants. Thus participants were aware of the concept but they had not been given a demonstration of how the Big Ideas are presented in the Go-Lab repository and the different functionalities that involve them. However, it should be noted that since these teachers were pilot teachers, this wasn’t the first time they visited the repository. Thus, we consider their answers to be those of an unbiased average user who has navigated the repository at least once before but never participated in a presentation specifically designed about the Big Ideas of Science. The questions used during the test are presented below:

Questions for navigation in the portal

While in the GoLabz main page

1. Let’s say you want to find a lab to teach your students about energy. Where would you click on the page?
2. How did you navigate in the page you clicked?
3. Now try to make a query using the Big Ideas of Science. Where did you click in order to do that?

While in the Preview page of the lab

4. Can you now find another lab that has a common Big Idea? How did you find it?

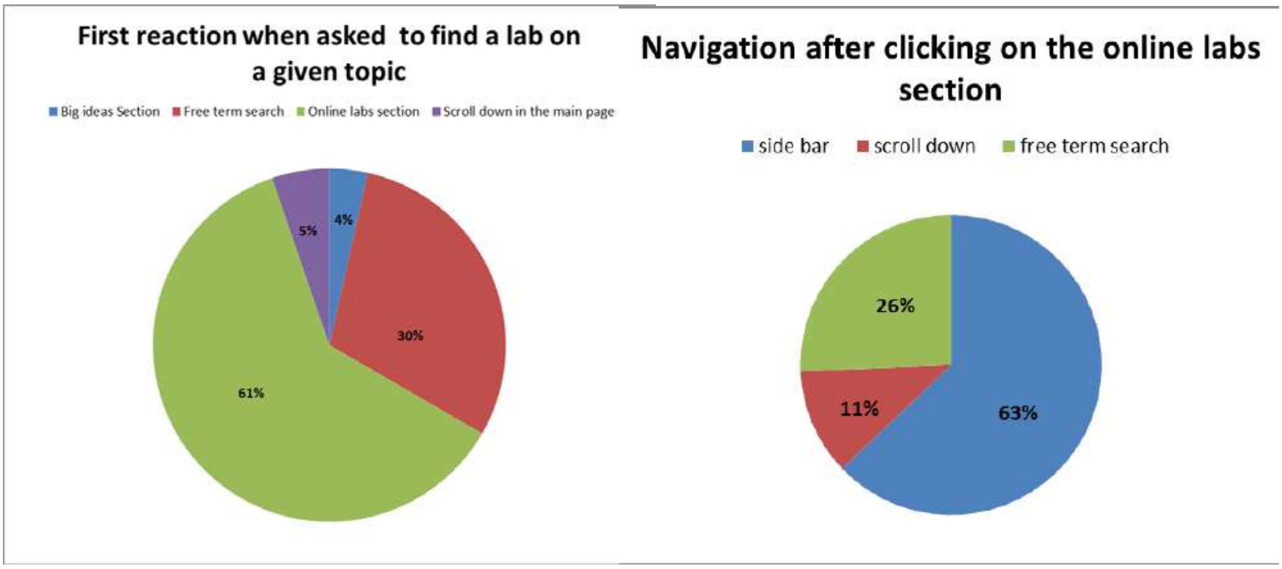
While in Big Ideas of Science tab

5. How would you characterize this page?
6. Do you like the presentation of the BI?
7. What purpose do you believe it serves?

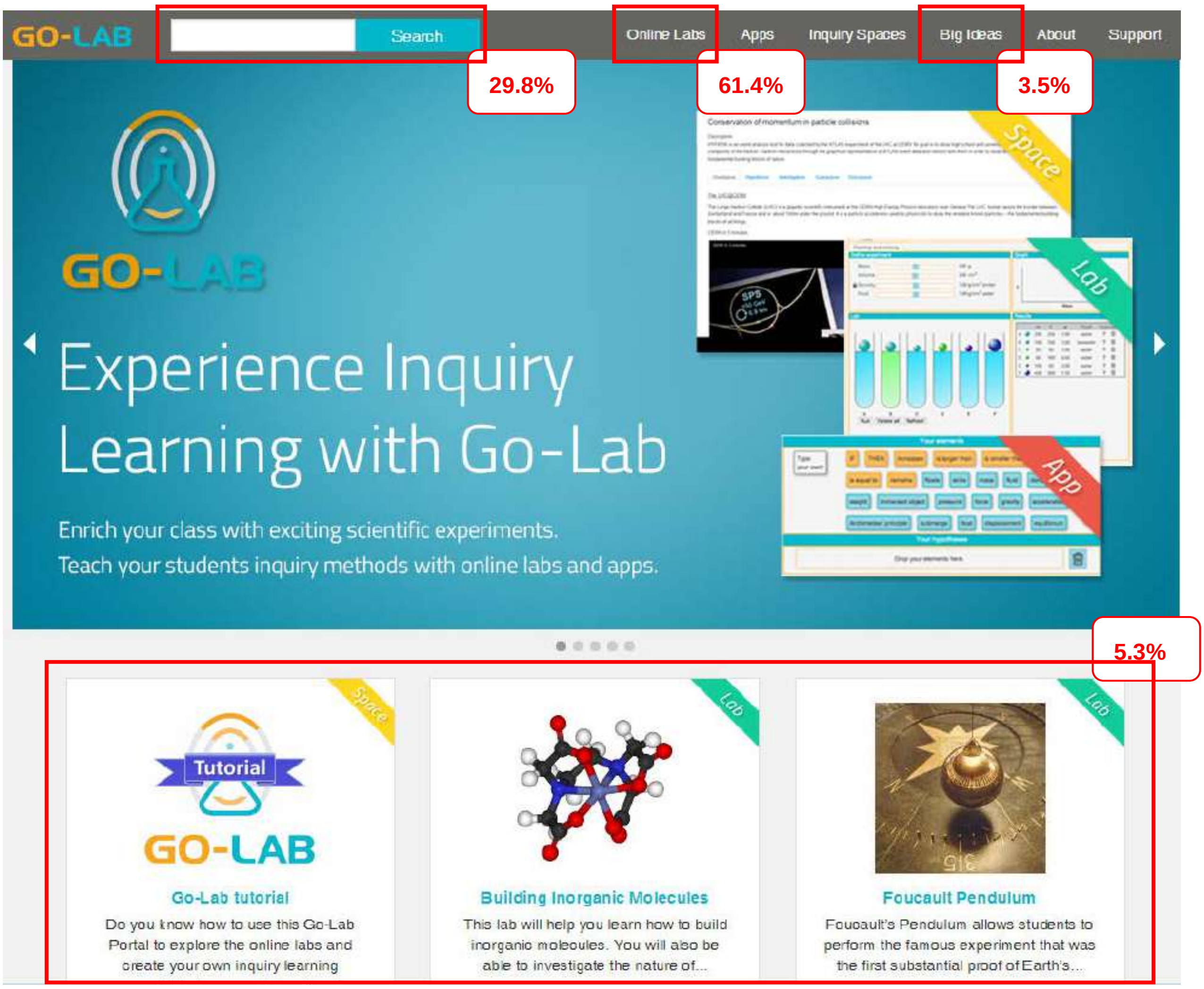
4.2.2. Usability test Results

Searching patterns

Question 1 and 2 from the list above aimed to define the searching patterns of users. More specifically, what we aimed to identify is what would be the first choice if they wanted to make a search on a specific subject. Although these two questions are not directly related to the use of Big Ideas as a recommendation system we chose to begin our test with these questions so as to check the degree to which they can use the search options in a meaningful way. Our expectations were that the majority of users would use the free search and the online labs section. The Big Ideas section provide an alternative searching option which focuses on finding multiple labs (and ILSs) that are connected to each other and no single labs. Thus we do not expect the Big Ideas section to be a popular choice. The results of the two first questions are presented below:



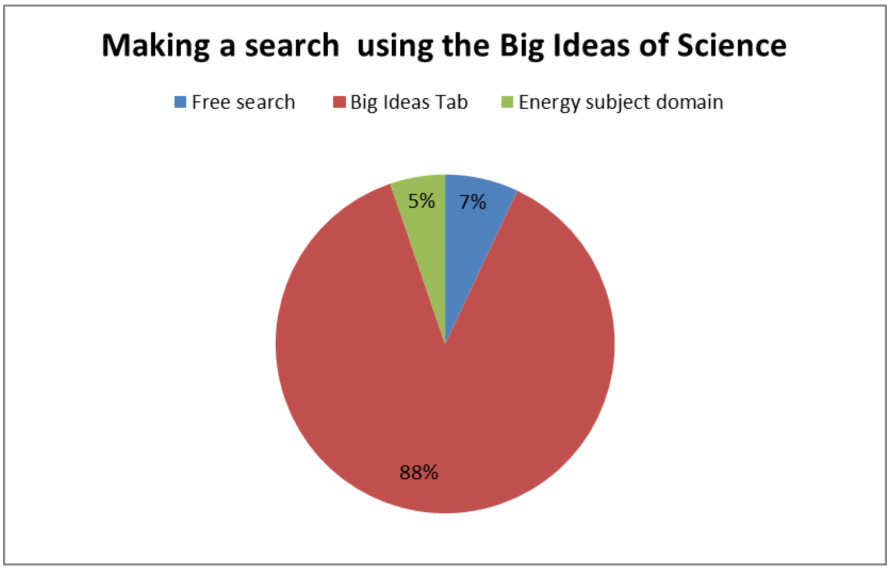
As seen in the graphs above, the majority of users (61%) chose to click on the online labs section while 30% chose the free text search. This result is in accordance to our expectation. Out of the 61% that chose to click on online labs tab 63% used in turn the side bar while 26% chose to use the free term search. These results indicate that 74% of the users navigated in the online labs section in a meaningful way (used the side bar or scrolled down) while 26% chose the free search term so the basically cancelled their previous choice as the free term search is not limited to retrieving online labs. Thus, overall 84.2% of the users navigated in the portal in a meaningful way. It is most likely that the users that first clicked on the online labs and then used the free text search thought that by clicking on the online labs section first and then on the free text search they narrowed down the free text search to retrieving only online labs.



The users that had the free terms search as their first choice, all typed in the word 'Energy' and managed successfully to retrieve a lab on Energy. All the users who chose the Big Ideas tab clicked in turn the first Big Idea which is about energy and managed successfully to retrieve a lab on Energy. The 5.3% of the users who chose to scroll down, could not tell which ones where on energy so they clicked on a lab at random and where not able to retrieve a lab.

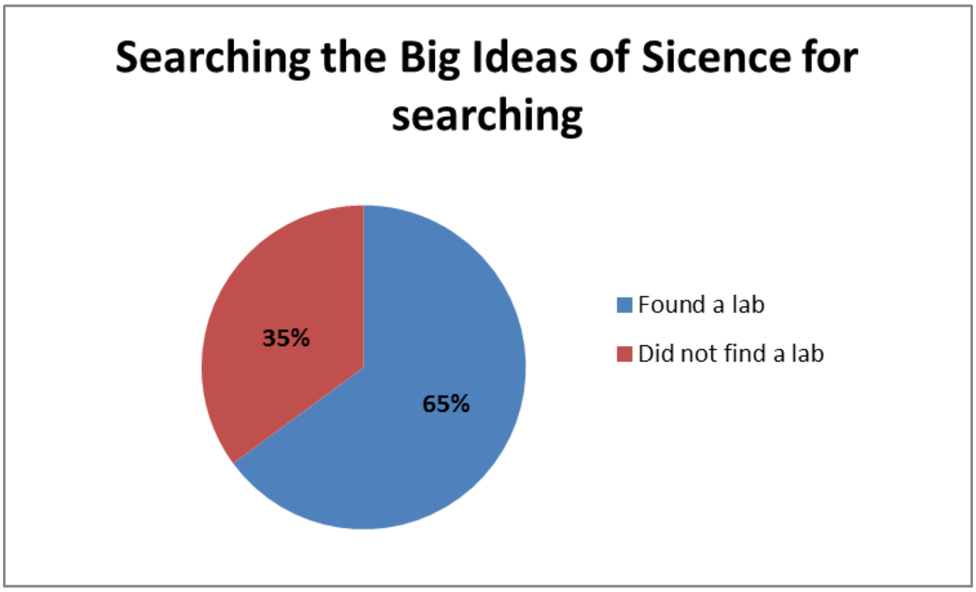
Searching using the Big ideas of Science

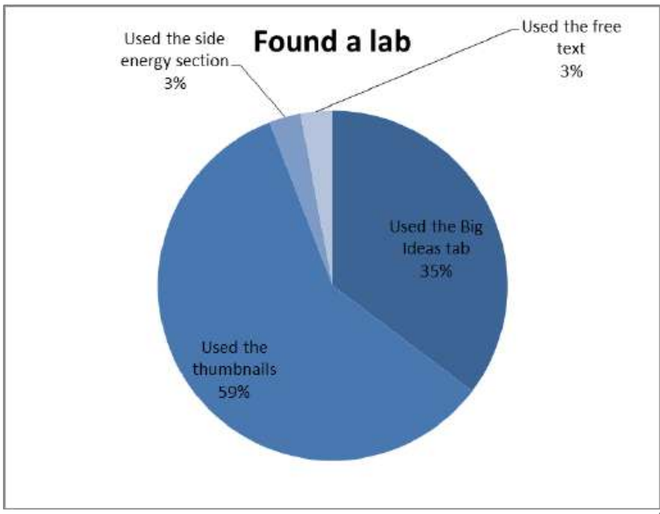
The next question (question 3) encouraged users to make a new query (subject free this time) using the Big Ideas of Science. The results of their navigation patterns are presented below. As seen in the graph below, 88% of the users chose to make their query using the Big Ideas tab. Only 12% chose another way to navigate. All users who selected the Big Ideas tab, scrolled down the list of Big Ideas, selected that they found appealing and they in turn selected a lab which they found interesting. They selection of Big Ideas varied based on their teaching subject. This result leads as to strongly believe that the Big Ideas of Science tab is in a prominent position and easy for teachers to find it and use it.

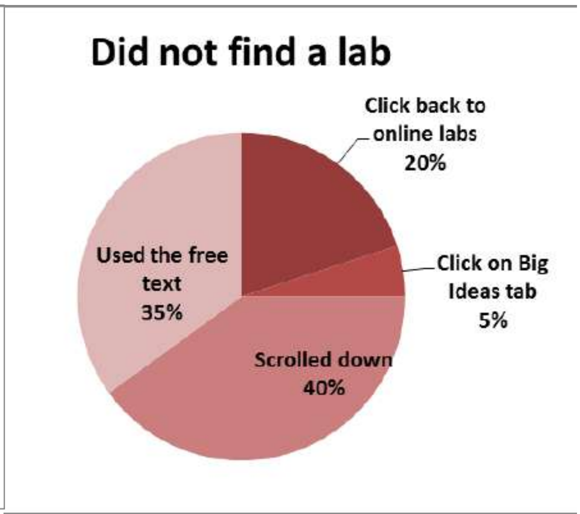


The Big Ideas of Science, as a recommendation system

The last question which involved users navigating in the repository was about using the Big ideas of Science as a recommendation system. Users where asked to choose an online lab at random and in turn try to find another lab which had at least one Big Idea in common with the first one. Our expectation in this part of the test was that teachers would choose to click on one of the orange thumbnails which represent the Big Ideas of Science related to the lab. The results of their navigation are presented below.







As seen from the graphs above, 65% of the users managed to find another lab with common Big Ideas while in the preview page of a lab. Out of this 65%, 35% used the Big Ideas tab and 59% used the Thumbnails under the preview image of the lab. One important finding is that overall, 59.6% of the users did not use the thumbnails under the preview image which are placed there to allow the users to find easily labs with common Big Ideas. People who did not use the thumbnails stated that they did not know what they were so they did not pay any attention to them.

4.2.3. Users opinion on the presentation and use of the Big Ideas

When particiants were asked to characterize the page of the "Big Ideas of Science", practically all of them gave us positive feedback. Only 3 answers out of 57 (5%) were negative; one mentioning that the page is too long, and the other two mentioning that the pictures could be better. As for the positive answers (95%) we represent them with a word cloud below Figure 21. Note that the question was to 'characterize' the page so it was expected that participants would use single adjectives rather than complete sentences.

Figure 21: Participants opinion on the presentation of the "Big Ideas of Science" in GoLabz.

When asked about the presentation of the "Big Ideas of Science", and whether they would change something, 41 out of 57 answers (72%) included no suggestions and they only mentioned that they liked the presentation of the "Big Ideas of Science" as it is currently done. The remaining 15 answers (28%) included some additional suggestionds. Out of these 15 answers, 13 (87%) made the same point.These answers suggest that the presentation of the Big Ideas could be better if no scrolling down was needed. Participants mentioned that although they like the presentation they would prefer to be able to see all Big Ideas in one screen and not have to scroll down.

The last question of the test was about the purpose of the “Big Ideas of Science”. In this question 42 out of 57 answers (74%) state that according to the participants understanding the role of the Big Ideas is to connect the different science subjects and organize the labs and activities based on them. The 15 remaining answers (26%) indicate that these participants perceive the Big Ideas more as a tool to be used directly in class to help the students understand scientific aspects and understand the connections bewteen science subjects.

4.2.4. Conclusions and recommendations

Based on the findings presented above, we conclude that when users search for labs, the search patterns they follow are the expected ones, meaning the free search and the online labs section. When it comes to searching with the Big Ideas of Science, teachers found the Big Ideas of Science tab easily and the vast majority of them managed to navigate through it successfully. Thus, we recommend no changes with regards to the position of the Big Ideas of Science tab in the main page of the portal. One recommendation that could however help in introducing the Big Ideas of Science to teachers when visiting the repository for the first time is the addition of an image about the Big Ideas of Science in the slide bar of the front page. On the subject of using the Big Ideas of Science as a recommendation system our results indicate that the majority of them can manage to use them successfully. However the number could be improved significantly. Based on the fact that 59.6% of the users did not use the thumbnails as expected, we conclude that the presence of these thumbnails is not apparent to the users. This may also be the reason why 35% did not manage to retrieve a lab with common Big Ideas. To this end we recommend that a short title is placed on top of the thumbnails that explains their use. This title could be for example “Find labs using the Big Ideas of Science” or “Find related labs using the Big Ideas of Science”. Another addition that we believe could increase the use of the “Big Ideas of Science” as a recommendation system is their addition in the side bar of the repository.

Based on teachers’ answers in the usability test, one other change that could be considered is the re-arrangement of the “Big Ideas of Science” tab so that all the Big Ideas are presented in one screen.

Finally, the overall presentation of the Big Ideas in the Go-Lab portal is such that it allows the users to understand their role in the repository and their use as a way to arrange and organize the online labs and inquiry learning spaces in order to demonstrate how they can be connected in an interdisciplinary framework. In other words the “Big Ideas of Science” facilitate the orchestration of the labs in such a way so that it is clear to teachers how to use them combined, harmonically and meaningfully.

4.3. Going beyond: Stakeholders opinion on the "Big Ideas of Science"

After concluding our work with validating the "Big Ideas of Science" with teachers and teachers' trainers, we decided to go a step further and investigate stakeholders' opinion on the matter.

In the framework of our research we consider the following groups to be stakeholders:

- Members of ministries of education and institutions responsible for curriculum development
- Researchers and educators from universities and institutes responsible for building science activities for schools in their country.
- Heads of laboratories of science teachers' education and heads of teachers' training centres
- School principals (School principals can take up the initiative to introduce the Big Ideas of Science in their own school as a way of organizing multidisciplinary activities. To this end we consider them as a part our stakeholders group)

The project's team communication with stakeholders regarding the Big Ideas of Science has three main objectives:

- Present the Go-Lab set of Big Ideas of Science;
- Present the teacher's and teacher trainer's view on the Big Ideas of Science based on the results of our research;
- Discuss the possible ways the Big Ideas of Science could be used in schools or be integrated in the science curriculum of their country.

To carry out our research, we approached and interviewed stakeholders from different countries (see Annex D for the invitation letter). The interview questions are presented below.

The face-to-face interviews had three parts:

- An introductory discussion so as to record the actions taken in order to interconnect different science subjects in their country.
- A presentation of the Go-Lab Big Ideas of Science set as well as the results of our research.
- Discussion on: a general first comment and impressions on these findings and follow-up clarifications if needed. Discussion based on a set of questions regarding the issues mentioned above.

The discussion structure is presented below:

Introductory questions:

1. Do you believe multidisciplinary activities are beneficial for students? Why?
2. Does the analytical programme of your country include multidisciplinary activities on science subjects?
   a. If yes: How are they organized?
   b. If no: Has there ever been an effort to include multidisciplinary activities?
3. Have you ever heard the term "Big ideas of Science" before? What do you think it is about?

Exploration questions (after the presentation of the Go-Lab BI and teachers' opinion)

4. How would you characterize the Go-Lab set of BI? Is it complete and appropriate for students?
5. Would you use it to help students make sense of natural phenomena or phenomena they come across in their everyday life?
6. How do you believe it can be used to help build multidisciplinary activities and connect different science subjects?
7. How do you think this set could be used in the school classrooms of your country in order to connect science subjects and promote multidisciplinary activities?
8. If it were up to you, to propose a framework that would promote multidisciplinary activities how would you envision it? Would you use such a structure?
9. Do you believe that the integration of such a structure would be a beneficial addition for the science curriculum of your country? Would you be willing to promote it?

Exit Question

10. Is there anything else you would like to add or comment on?

Note: The presentation used during the interview is available in Annex E.

4.3.1. Interviews' Results

In the framework of our research we interviewed the following eighteen (18) people:

Name	Affiliation	Country
Maarten Pieters	Curriculum Developer/professional expert in Nature & Technology@ the Netherlands Institute for Curriculum Development	The Netherlands
Garganourakis Vassilis	Chairman of the Hellenic Association of the Directors of Science Laboratory Centers	Greece
Demetrios Phillipou	Chairman of the National Physics Society	Cyprus
Joao Carlos Sousa	Head of education ICT science projects at the general directorate of education in the ministry of education and science in Portugal	Portugal
Luis Zaballos	Advisor at the innovation department of the ministry of education.	Spain
Cristian Stultz	President of the Swiss-German physics commission (DPK)	Switzerland
Nancy Verbeke	School Headmaster, Middenschool Geel	Belgium
Emanuela Antolini	School Headmaster, IC B. Lorenzi - Fumane VR, Fumane	Italy
Edward Comez	Education Director of the Las Cumbres Observatory Global Telescope Network	United Kingdom
Hassane Darhmaoui	Associate Professor of Physics School of Science and Engineering at Al Akhawayn University in Ifrane	Morocco
Kevin Govender	Director of the International Astronomical Unions Office of Astronomy for Development	South Africa
Avivah Yamani	Associate of International Astronomy Union	Indonesia
Claudio Moises Paulo	Lecturer at Eduardo Mondlane University at Mozambique, Coordinator of Astronomy Activities	Mozambique
Sergio Cabezon	Designer & Outreach Coordinator at Manthan Educational Programme Society	Chile
Kathan Kothari	Professor at the Physics Department of the Universidade Federal do Rio Grando Norte.	India
Jafelice Luiz Carlos	Organizer of activities to improve the curriculum and to give extra-mural courses (retired a year ago)	Brazil
Carl Pennypacker	Professor at the University of California, Berkeley and the Lawrence Berkeley Laboratory, principal investigator for the Hands On Universe project.	USA
Hidehiko Agata	Doctor of Education at the National Astronomy observatory of Japan	Japan

In order to present the views of the interviewees we divided them in two groups. Those coming from countries which participate in the Go-Lab pilot phases, and those which don't. Out of the eighteen (18) people we interviewed, one was not in favour of using multidisciplinary activities in the school classroom. Where needed, we present the answers given separately.

1. Do you believe multidisciplinary activities are beneficial for students? Why?

Go-Lab Pilot countries

Multidisciplinary science activities can be beneficial as they provide input from many disciplines thus helping students making links between different subjects. In addition they can encourage teachers of different disciplines to collaborate in a productive framework. Teaching science using multidisciplinary activities is also essential because in fact, this is how nature is; the different disciplines are a human invention so as to allow us to better study different subjects in more detail. But nature in general is not like that and it is essential for students to understand this.

According to one stakeholders' view, multidisciplinary activities are not beneficial for students. They are more likely to confuse them rather than help them.

Other countries

It is very important to have multidisciplinary activities. Science is also linked to everyday life. If we want to make that link for students we need to combine all different sciences together. Such a context that is exciting and that it inspires the students can be very beneficial for them.

2. Does the analytical programme of your country include multidisciplinary activities on science subjects?

Go-Lab Pilot countries

All countries have some room for multidisciplinary activities. Opportunities however to do such activities grow shorter in higher classes. In addition, such activities in many cases need to be in complete accordance with the curriculum of different disciplines which can be challenging for teachers. They sometimes find it difficult to collaborate and they have a lot of time restrictions.

Other countries

The majority of countries do not have room for multidisciplinary activities but efforts are being made towards that direction. In some other case (South Africa, Indonesia, Brazil), although there is some room for such activities, teachers very rarely choose realize them in class. In general, teaching follows more traditional approaches that focus more on memorizing rather than thinking critically.

3. Have you ever heard the term "Big ideas of Science" before? What do you think it is about?

Go-Lab Pilot countries

The majority of stakeholders were already familiar with the concept. According to their understanding the "Big Ideas of Science" is a combination of ideas that can be used as a core structure to help people understand the universe and our surroundings. Interviewees from Cyprus and Portugal were not familiar with the term, at least not in the framework of science education.

Other countries
None of the interviewees was familiar with the concept. The majority of them perceive it as a new methodology of teaching science or for activities in which students can understand better the science and start to like it.

Exploration questions (after the presentation of the Go-Lab BI and teachers' opinion)

4. How would you characterize the Go-Lab set of Big ideas of Science? Is it complete and appropriate for students?

Go-Lab Pilot countries
The Go-Lab set is quite coherent and it covers all the basic concepts. However, as most stakeholders pointed out, they would need much more time to study the set so as to be absolutely certain that nothing is missing. Regardless, it is quite concise and complete and thus it can be a good basis. It is important to communicate these concepts to students, although it is doubtful that they will be in position to fully understand them right away. To this end it is important that their communication is done in an ongoing basis and that teachers are trained in using this set. In addition, the degree of multidisciplinarity is not the same for all Big Ideas. In some cases the connection between the multidisciplinary activities and the Big Ideas may not be evident. A representation with the scales of the universe could be very useful for students to understand the level of multidisciplinarity of each idea.

Other countries
It is a good summary and a complete one. More time would be needed to know for sure if it is complete. It can be used with students and linked to the curricula of the countries involved. It could also be used to make links with everyday life and help students understand the universality of different phenomena.

5. Would you use it to help students make sense of natural phenomena or phenomena they come across in their everyday life?

Go-Lab Pilot countries

The Big Ideas could help students understand natural phenomena and give scientific explanations provided that they are properly communicated by the teachers. Teachers need to use the set extensively in school so that students don't just learn these Big Ideas but so that they reflect on them through examples or even construct them themselves and make the connections. Some Big Ideas could be more difficult for students to understand than others. The proper communication of these ideas would require of teachers to be pedagogically inventive and have a very clear understanding of these ideas themselves so that they can construct appropriate activities.

According to one stakeholders' view, each idea includes huge information which students would have to understand. So it is doubtful that such an approach would be beneficial.

Other countries
This set of Big Ideas of Science could be very helpful for this purpose. What's important is that it should be made clear that when this set is presented it is not communicated as 'the only truth'. It should be made clear that this is based on our current knowledge and based on the specific way and the point of view we perceive our world from. In addition,

adaptations would need to be made depending on the country/region. There are many countries/regions where there is a very strong influence of culture and superstition and there is no connection with science teaching in general. So, it would require some effort to adapt such a set based on the special characteristic of each society.

6. How do you believe it can be used to help build multidisciplinary activities and connect different science subjects?

Go-Lab Pilot countries

If such a standard set is communicated to students, through activities that will vary in time (depending on the complexity of the idea) it will facilitate them in learning this overarching set of ideas that describe our world. It would require plenty of preparation from teachers and carefully designed activities. Such a set can also provide different layers of learning. Teachers of different subjects could collaborate, match activities coming from different disciplines and communicate the same unifying concepts. In any case, there would be a need to map the set with the curricula of each country.

According to one stakeholders' view, teachers have the curriculum which they have to follow and they cannot deviate. Interdisciplinarity involves so many things that makes it impossible for teachers to go deep enough because of time restrictions. In addition, the workload of the programme is too much to afford multidisciplinary activities.

Other countries

This set could indeed be used for such a purpose. It could facilitate the teachers in synchronizing their teaching, or even present certain themes together. These Big Ideas can be explored through exhibitions where children interact, learn and link them with everyday environment. There can also be a lot of self-learning materials and educational materials that students use at home.

7. How do you think this set could be used in the school classrooms of your country in order to connect science subjects and promote multidisciplinary activities?

Go-Lab Pilot countries

The mapping of these ideas with the curricula of each country would be a first step. In order to do that effectively what would also be necessary is to go through the several layers leading to these ideas and map them to the curricula as well. Other than that, another essential issue is to convince the teachers to use it. As many teachers are used to only teaching about their own discipline, such a set could take them out of their comfort zone. So it would be difficult for them to accept it. On the other hand, in some countries, teachers are asked to teach classes of other disciplines as well. In these cases, such a set could be a very useful tool for them. In both cases teachers would have to be properly trained and have access to activities and relative materials.

According to one stakeholders' view, these ideas cannot not be used in the school classroom. Some of these are fundamental in physics for example. So, they need to be taught separately and make sure that students understand them.

Other countries

If teachers were encouraged to collaborate and receive training this set could be used in school classrooms. However, in some countries like, South Africa, Mozambique, Chile and India due to the diversity it could be used only in the cases of some schools and not in the whole country. Private schools or affluent schools would be better options.

8. If it were up to you, to propose a framework that would promote multidisciplinary activities how would you envision it? Would you use such a structure?

Go-Lab Pilot countries

A structure like that could be valuable and a good starting point for promoting multidisciplinary activities. A repository which would connect different activities and that examine the same concepts from different disciplines would be very beneficial. The creation of activities for each Big Idea could be an important addition. The revisiting and reflecting of the activities would also be important. Teachers who excel in building activities could also be a reliable help.

Other countries

A framework including the Big Ideas of Science would be beneficial and it could be used to organize multidisciplinary activities. However, it is imperative to link it to national curricula and have teachers receive proper training if it is to be used nationwide. All stakeholders agreed that they would consider using it in their country. In fact, stakeholders from Indonesia, Mozambique, India stated that they will consider using it in next year in small scale pilots.

9. Do you believe that the integration of such a structure would be a beneficial addition for the science curriculum of your country? Would you be willing to promote it?

Go-Lab Pilot countries

Such an integration would indeed be beneficial. It would be good for students to be show them other perspectives as well and present to them how the same concept or phenomenon or context is handled by different disciplines. Separate disciplines however, have a big value too so the Big Ideas could be used as an addition to the current curricula of countries. Stakeholders coming from the The Netherlands, Greece, Spain and Portugal mentioned that they would be willing to promote it and do some pilots to see how it works.

According to one stakeholders' view, some of these ideas are self-evident. They should be taught separately and in a specific order. It is not really a matter of in how many big ideas we end up. Within each discipline, physics for example, the connections are very clear.

Other countries

All stakeholders agreed that they would be willing to promote it in the framework of science teaching. In some cases like South Africa, where diversity is very high, it would be difficult to integrate it in most schools; private schools could however be a good start.

Exit Question

10. Is there anything else you would like to add or comment on?

Go-Lab Pilot countries

This alternative way of organizing themes and activities is very interesting and useful. As in many countries the curricula change very often, the organization of activities based only on the curricula is quite problematic (and yet necessary). The Big Ideas is a very smart way to overcome this problem if we organize activities using them on top of traditional organization schemes. This work with the Big Ideas could also have extension to disciplines beyond science. There could be extension to social sciences, history and the teaching of languages.

According to one stakeholders' view, in theory such an approach sounds good. The problem is when you put theory in practice. It is not clear what would happen in class. Teachers have time constrains and principals are quite conservative and rarely allow teachers to deviate from the analytical programme. Some things need to be integrated in the curriculum if there is any chance of being actually realized.

Other countries

Interviewees from Mozambique, Indonesia and India stated that they will try talking to their ministers and introduce the idea and maybe do some small scale trials.

4.3.2. Conclusions

Based on the thirteen interviews we conducted with stakeholders from different countries worldwide, we conclude that multidisciplinary science activities have potential and that they can help students understand the connections between different subjects. All but one of the interviewees were in favor of including such activities in the schools of their countries. However it is still challenging for teachers to work on such activities mostly due to time restrictions and lack of collaboration between them.

The Big Ideas of Science is in general characterized by stakeholders as a quite complete set which could be used as means to promote multidisciplinary activities and help students make sense of natural phenomena. However, in order to facilitate the students grasping these ideas it is imperative that they are repeated throughout their school life and that they are provided with example activities that will allow them to reflect on them and assess them. This would mean that in order to introduce such an approach teachers would have to be trained and be provided with materials properly designed. The organization of activities in the Go-Lab repository can facilitate teachers in that matter as they are organized based on the Big Ideas of Science on top of the traditional subject-based and age-based organization. One important point that should also be made clear while communicating the Big Ideas of Science to students is that this is not 'the only truth'; it is a set of ideas based on how we interpret our world and based on our current knowledge.

In addition, the introduction of the Big Ideas of Science to schools could be a good starting point for teachers of different disciplines to start collaborating and synchronizing their teaching. However, in order to achieve this, two actions need to be taken. First, it is imperative that there is a mapping of these ideas, as well as of their underlying concepts to the science curricula of countries. Second, teachers need to be properly trained in order to use them effectively.

When it comes to envisioning a framework that promotes multidisciplinary activities, stakeholders agree that if teachers are provided with proper training and activities, the Big Ideas of Science could be of great use. One additional positive consequence of organizing activities using the Big Ideas of Science, like it is done in the Go-Lab repository, is that it goes beyond national curricula. This is beneficial because curricula in many countries are restructured quite often and this is confusing for teachers. Thus, an organization of activities that is not affected by curriculum changes could be used as a good reference point.

Finally, with the exception of one, all other stakeholders stated that they would be willing to promote the Big Ideas of Science in the framework of science teaching, present it to the ministries of their countries or do small pilots in their local schools.

5 Establishing a Communication Hub between Lab Owners and the Go-Lab Teacher's Community

Aside from offering the opportunity to teachers to use different science online labs through the Go-Lab repository, it is also important to establish a communication hub between them and the lab owners. We believe that the direct communication between teachers and lab owners will benefit both parties as the teachers will be able to get direct support when needed and communicate their ideas, while lab owners will have the opportunity to received important information about their labs, which will allow them to further improve them based on users' opinion. Moreover, aside from ensuring the possibility that teachers will be able to communicate directly with lab owners, we have also taken into consideration ways with which lab owners will be able to receive feedback from teachers indirectly, through a statistics page.

Overall, the actions taken so as to allow the communication of information between lab owners and teachers are listed below:

- **a.** Access to the lab owners' e-mail for direct contact;
- **b.** Comments section in the preview page of each lab;
- **c.** Lab owner's statistics page in the Go-Lab repository;
- **d.** Invitation to lab owners to participate in the Go-Lab tutoring platform;

5.1 Access to the lab owners' e-mail for direct contact

When lab owners add a lab in the Go-Lab repository, they have the option of adding their contact information as well so that users may contact them directly (Figure 22)

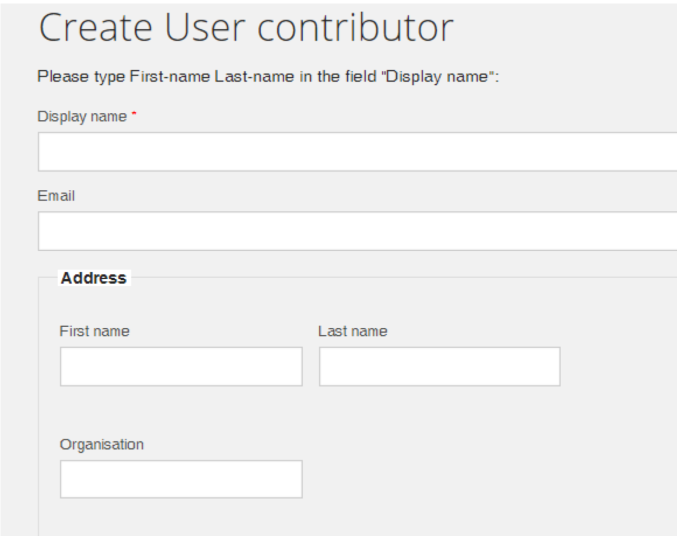


Figure 22: Part of the form for adding lab owners' contact information.

Thus, when adding a lab this information will be displayed in the preview page of the lab (Figure 23). This way, when a problem occurs or if teachers want to make suggestions for improvements they can send their feedback to the lab owner directly.

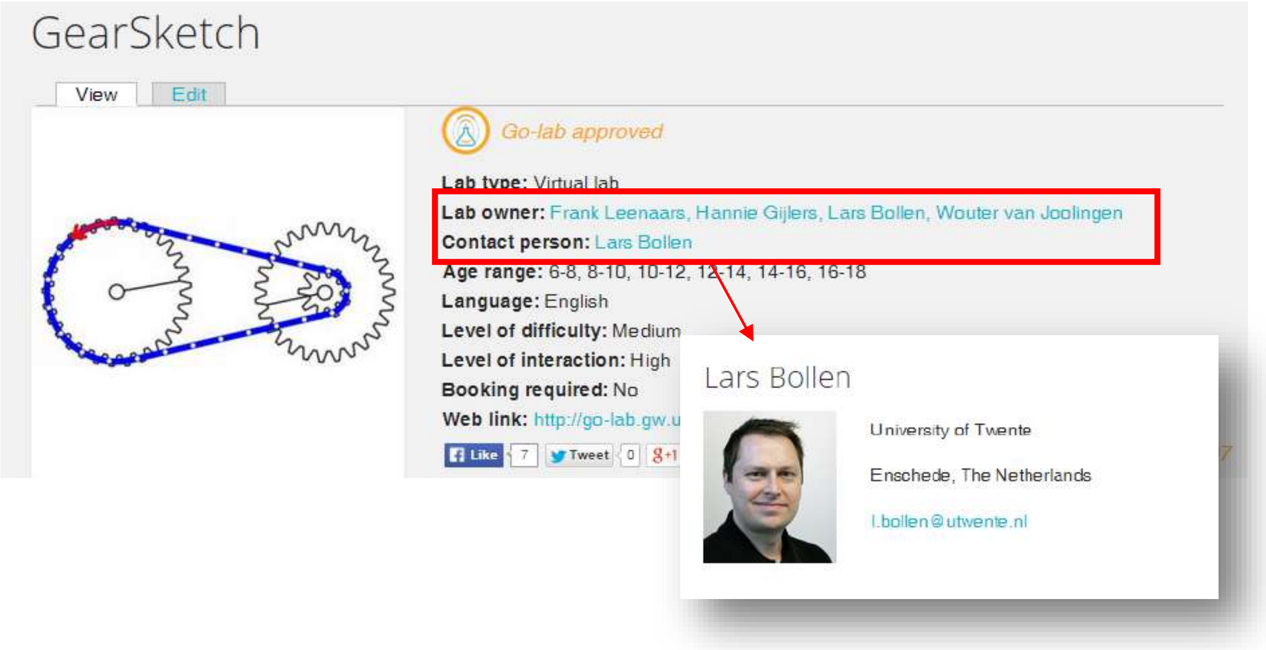


Figure 23: Lab owner's contact information displayed in the preview page of a lab.

5.2 Comments Section in the Preview Page of each Online Lab

In addition to making available the lab owner's information, there is also the option of adding a comment in the preview page of a lab. This way, users will be able to leave comments that will be available to the lab owners as well as other users. Through this section lab owners can also get an overall idea about what teachers think of their lab. In addition, through the subscribe button at the bottom of the comments section, lab owners can choose to be notified every time a user posts a comment for their lab.

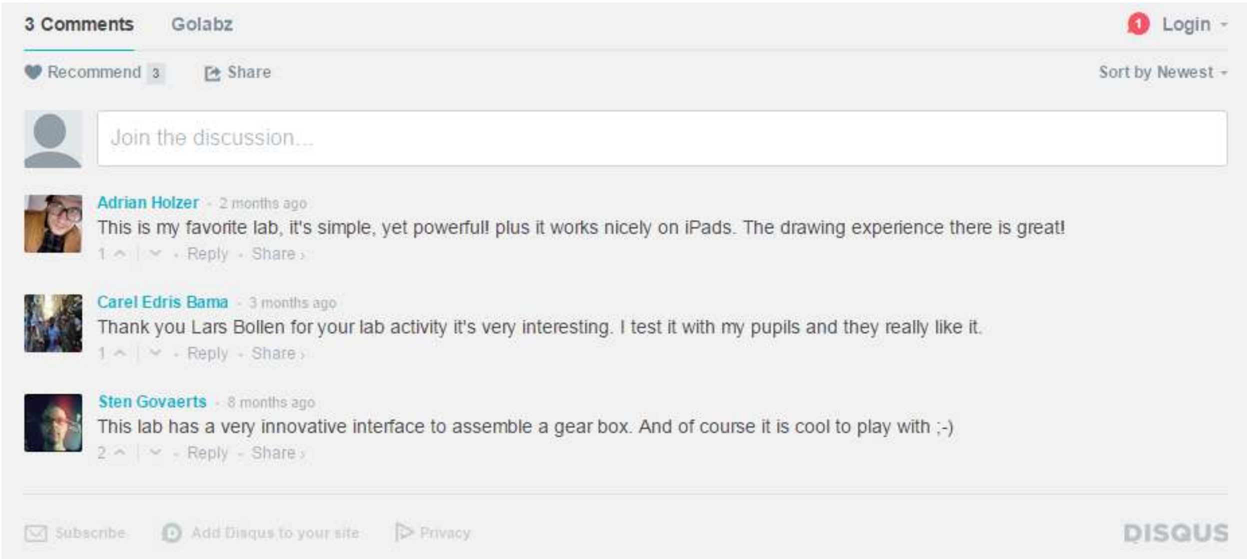


Figure 24: Comments section available in the preview pages of labs.

5.3 Lab Owner's Statistics Page in the Go-Lab Repository

On top of creating the necessary channels for direct communication between lab owners and teachers, we also aim to provide lab owners with some statistical information about their lab. Such data can be useful to lab owners and help them further improve their lab and get an overall idea about its use through Go-Lab. More specifically, the main information that we suggest to make available are the following:

Table 14: Statistical information offered to lab owners

Lab visits	Exit Rate
Lab Hits	Number of ILSs created
Entry Hits	Number of times used
Visit Length	Number of terms in search
Bounce Count	Exit Rate
Exiting visits	Visitors vs Returning Visitors
Time spend	Lab use per month
Bounce Rate	Demographics

These statistics will be made available to the lab owners through a separate tab in their profile in the Go-Lab repository (Figure 24).

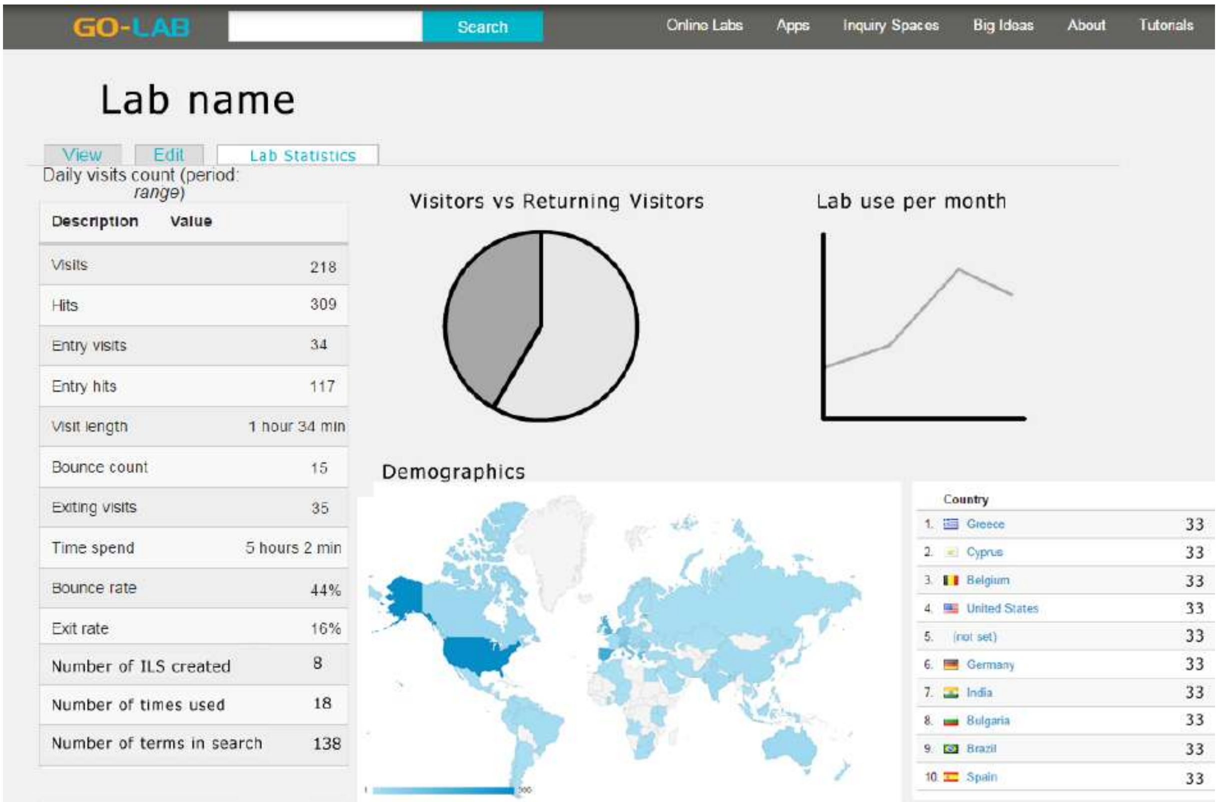


Figure 25: Mock-up of statistics page for lab owners.

5.4 Invitation to Lab Owners to participate in the Go-Lab Tutoring Platform

Aside from offering the means to allow the communication between teachers and lab owners through the Go-Lab repository as well as offering to the latter statistical data about their lab, we also plan to encourage the communication between those two groups through the Go-Lab tutoring platform. Upon registration to the Go-Lab repository, lab owners will be presented with the Go-Lab tutoring platform and invited to become tutors and offer courses about the use of their labs to the Go-Lab teachers. This way direct online communication will also be possible.

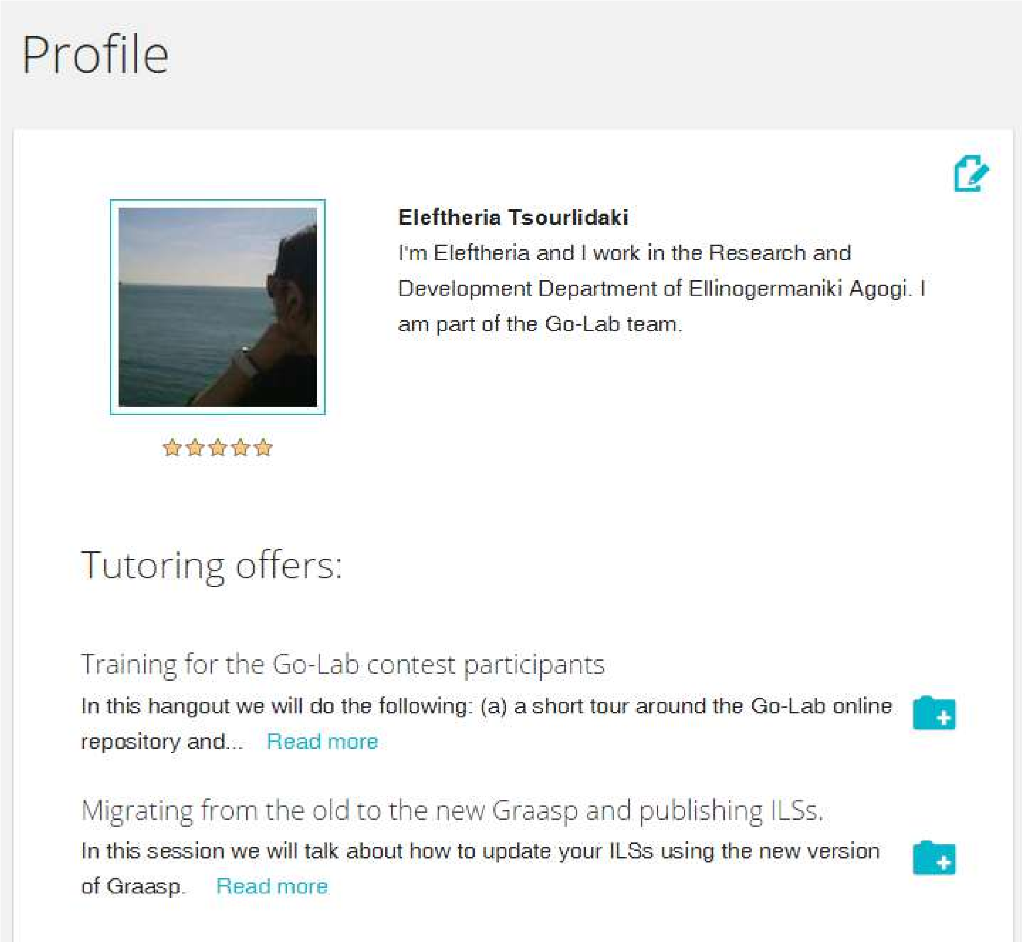


Figure 26: The profile page of a tutor in the Go-Lab tutoring platform.

6 Validating the Metadata Model of the Go-Lab Inquiry Learning Spaces

The aim of this section is to present the work that has been done with users (namely **science teachers**) towards validating the metadata model of the **Go-Lab Inquiry Learning Spaces (ILSs).** The proposed metadata model has been already used for storing and classifying ILSs in the Go-Lab repository (http://www.golabz.eu/). In order to appropriately design our validation methodology, we reviewed studies from the literature that focus on validating metadata models of educational resources on related application domains. Table 15 presents briefly these studies along with their basic parameters.

Table 15: Studies on Validating Metadata Models of Educational Resources

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

As we can notice from Table 15, commonly used validation instruments are questionnaires through which end-users (teachers/trainers or subject domain experts) are asked to validate one by one the various **metadata elements** and their **vocabularies** of the proposed metadata model. As a result, a similar methodology has been followed in our case and it is described in details in the next section.***Study Methodology***

In this section, we present the methodology that has been adopted in our study. More specifically, we present the profile of the participants that were involved in our study, as well as the procedure that was followed.

6.1.1 Sample

Among the 516 school science teachers[2] who partially participated in the 2nd Go-Lab pilot phase, the study was conducted with **N=99** school science teachers. This means that the response rate was **19,18%.** Table 16 presents the distribution of the number of science teachers participated in our study in different European member states.

[2] Data retrieved on October 2014 (that was the beginning of 2nd Pilot Phase of the Go-Lab Project)

Table 16: Distribution of the participated science teachers in different European member states

No.	Country	Number of Teachers	% per Country
1	Portugal	38	38,3%
2	Cyprus	15	15,1%
3	Greece	13	13,1%
4	UK	8	8,1%
5	Germany	6	6,1%
6	Spain	4	4,1%
7	Estonia	4	4,1%
8	Belgium	3	3,1%
9	The Netherlands	2	2,0%
10	Italy	2	2,0%
11	Croatia	1	1,0%
12	France	1	1,0%
13	Ireland	1	1,0%
14	Norway	1	1,0%
Total		**99**	**100,00%**

As we can notice from Table 16, our sample includes school science teachers from fourteen European member states. The majority of our sample is teaching in Portugal (38,3%). Cyprus holds the second place with 15,1% (15 out of 99 total respondents) and Greece comes third with 13,1% (13 out of 99 total respondents). Moreover, we can notice that 8,1% of our sample is teaching in UK (8 out of 99 total respondents), 6,1% of our sample is teaching in Germany (6 out of 99 total respondents), 4,1% is teaching in Spain (4 out of 99 total respondents) as well as in Estonia (4,1%, 4 out of 99 total respondents), 3,1% is teaching in Belgium (3 out of 99 total respondents) and 2,0% is teaching in the Netherlands (2 out of 99 total respondents), as well as in Italy (2,0%, 2 out of 99 total respondents). Finally, Croatia, France, Ireland and Norway are represented with 1 teacher each (1,0%).

Moreover, we present an analysis of the profile of our sample. This analysis will help us to identify a solid professional and educational profile of the respondents in order to ensure valid answers to our study. To this end, Figure 27 to Figure 31 present the distribution of the science teachers participated in our study regarding their gender, years of teaching experience, level of education, ICT knowledge and ICT usage during teaching.

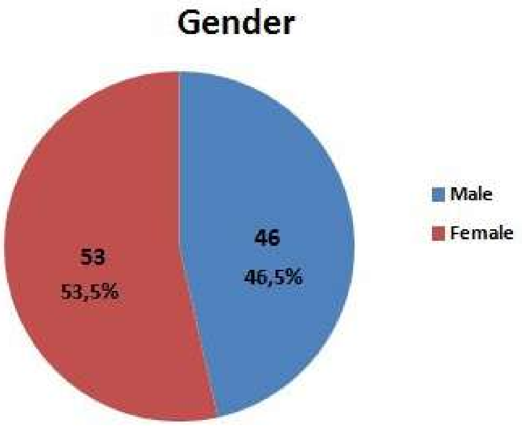


Figure 27: Gender Distribution.

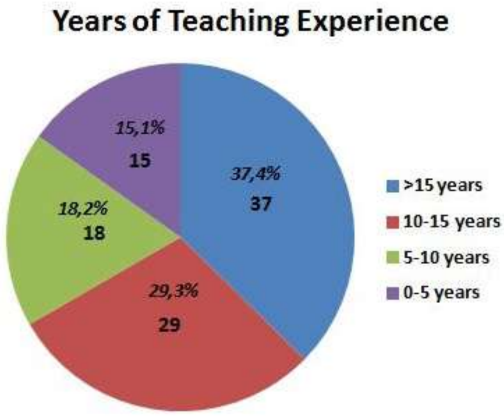


Figure 28: Years of Teaching Experience Distribution.

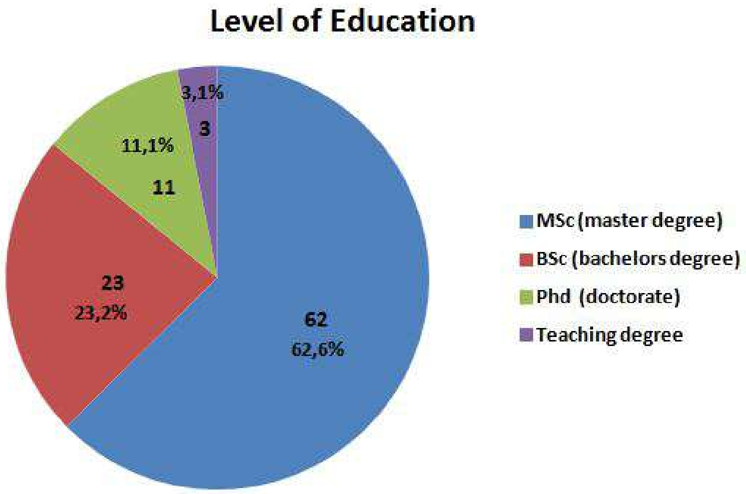


Figure 29: Level of Education Distribution.

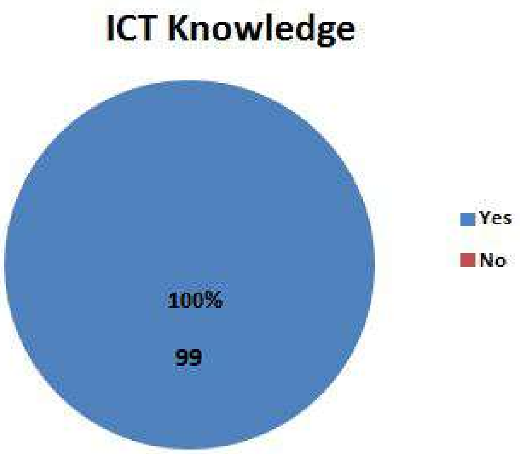


Figure 30: ICT Knowledge Distribution.

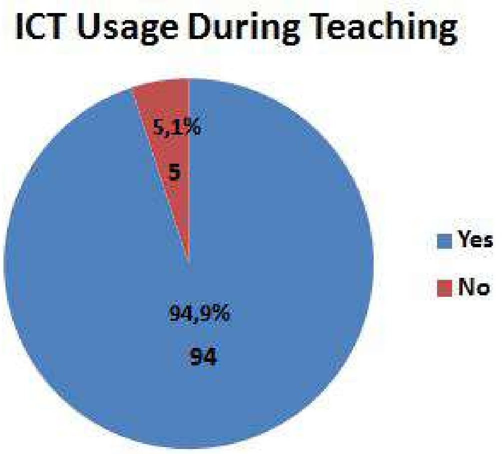


Figure 31: ICT Usage During Teaching Distribution.

As we can notice, there is a gender balance between the participants since there are 53,5% female teachers (53 out of 99 total participants) and 46,4% male teachers (46 out of 99 total respondents). The vast majority of the respondents have a solid professional teaching experience since 84,9% (84 out of 99 total participants) of them are professional teachers more than 5 years. Furthermore, as we can notice from Figure 28, 73,8% of the participants hold a post graduate degree (62 out of 99 total participants hold a Master Degree and 11 out of 99 total respondents hold a PhD), as well as, the 23,2% of them hold a Bachelor Degree. Not surprisingly, all teachers who participated in the validation process are competent in using ICT and 94,9% (94 out of 99 total participants) are using ICT in their teaching activities. Thus, we can assume that our sample has enough experience with technology-supported science teaching so as to provide valid answers to our questionnaires.

6.1.2 Procedure

In order to validate the proposed metadata model, we provided to the participating science teachers a questionnaire (Annex B). The aim of each questionnaire was to collect participants' opinions on the importance of certain metadata elements from our proposed metadata model.

More precisely, the teachers were asked to rate each metadata element with a five-point like scale, where 1 denotes "low importance" and 5 denotes "high importance" for the following there different contexts of use:

- Importance of Metadata Elements within the context of "***making a general search for inquiry learning spaces*"** in the Go-Lab repository.
- Importance of Metadata Elements within the context of "***filtering search results for inquiry learning spaces"*** in the Go-Lab repository.
- Importance of Metadata Elements within the context of "***viewing the preview page of a Go-Lab inquiry learning space***" in the Go-Lab repository

It should be noted that out of the 21 elements that are part of the metadata model (presented in D2.2 - The Go-Lab Inventory and Integration of Online Labs – Labs Offered by Universities), 18 were included in the questionnaire. Elements such as "Location URL" and "Description" were not included in the questionnaire, because we consider them essential for our proposed metadata model and thus no further investigation was needed on validating their importance. Moreover, two elements (namely ILS owner and ILS Contributor) were combined to one element, namely ILS owner and contributors.

In order to receive feedback from the participants based on the questionnaire that was designed, appropriate workshops were organized that had the following structure:

- **During the workshops:** all participants attended a demonstration of the Go-Lab repository. More specifically, the main functionalities of the repository, as well as the search and retrieval facilities were presented, along with the ILSs that were stored in the repository. Moreover, all participants could navigate within the Go-Lab repository during the workshop, with their personal devices (laptops or tablets) and use it themselves directly. Thus, they had a concrete idea of how ILS metadata elements have been deployed within the Go-Lab repository.
- **After the workshops:** all participants were asked to rate the ILS metadata elements by completing the designed questionnaire (presented in Annex B - Questionnaire for Validating the Metadata Model for Go-Lab Inquiry Learning Spaces).

6.2 Validation Results

This section presents quantitative data analysis results for participants' feedback regarding the importance of ILSs metadata elements for the different contexts of use (as described in section 4.1). More specifically, Table 17 presents the ranking of the importance of metadata elements within the context of "*making a general search for ILSs*" in the Go-Lab repository. Table 18 presents the ranking of the importance of metadata elements within the context of "*filtering search results for ILSs"* in the Go-Lab repository. Finally,

Table 19 presents the ranking of the importance of metadata elements within the context of "*viewing the preview page of an ILs in the Go-Lab repository*".

Table 17: Ranking of the Importance of Metadata Elements within the Context of Making a General Search for ILSs in the Go-Lab Repository

Ranking	Metadata Element Name	Mean	SD[3]
1	Inquiry Learning Space Title	4,36	0,84
2	Subject domains that the Inquiry Learning Space addresses	4,29	0,91
3	Keywords	4,23	1,06
4	Inquiry Learning Space Available Languages	4,15	0,83
5	Age Range that the Inquiry Learning Space can be used	4,13	0,93
6	Labs used in the Inquiry Learning Space	4,05	0,91
7	Educational objectives addressed by the Inquiry Learning Space	3,73	1,05
8	Average learning time of the Inquiry Learning Space	3,72	1,01
9	The Big Ideas of Science that the Inquiry Learning Space addresses	3,68	1,09
10	Students' prior knowledge needed to use the Inquiry Learning Space	3,65	1,00
11	Organizational Requirements needed to use the Inquiry Learning Space	3,61	0,98
12	The pedagogical scenario used in the Inquiry Learning Space	3,61	1,11
13	Status of the Inquiry Learning Space	3,58	1,17
14	Level of interaction of the Inquiry Learning Space	3,52	0,99
15	Additional materials included in the Inquiry Learning Space	3,51	1,04
16	Level of difficulty of the Inquiry Learning Space	3,47	0,99
17	Inquiry Learning Space Access rights	3,44	1,17
18	Inquiry Learning Space Owner and Contributors	3,07	1,24

Table 18: Ranking of the Importance of Metadata Elements within the Context of Filtering Search Results for ILSs in the Go-Lab Repository

Ranking	Metadata Element Name	Mean	SD
1	Inquiry Learning Space Title	4,37	0,72

[3] Standard Deviation

2	Keywords	4,36	0,79
3	Subject domains that the Inquiry Learning Space addresses	4,25	0,78
4	Inquiry Learning Space Available Languages	4,24	1,00
5	Labs used in the Inquiry Learning Space	4,23	0,86
6	Age Range that the Inquiry Learning Space can be used	4,19	0,74
7	Average learning time of the Inquiry Learning Space	4,00	1,06
8	Organizational Requirements needed to use the Inquiry Learning Space	3,89	1,11
9	Level of difficulty of the Inquiry Learning Space	3,89	1,05
10	Level of interaction of the Inquiry Learning Space	3,85	0,99
11	Students' prior knowledge needed to use the Inquiry Learning Space	3,84	1,09
12	Educational objectives addressed by the Inquiry Learning Space	3,83	0,96
13	Additional materials included in the Inquiry Learning Space	3,82	1,12
14	Status of the Inquiry Learning Space	3,76	1,25
15	The Big Ideas of Science that the Inquiry Learning Space addresses	3,75	1,01
16	The pedagogical scenario used in the Inquiry Learning Space	3,68	0,96
17	Inquiry Learning Space Access rights	3,59	1,18
18	Inquiry Learning Space Owner and Contributors	3,19	1,27

Table 19: Ranking of the Importance of Metadata Elements within the Context of Viewing the Preview Page of an ILSs in the Go-Lab Repository

Ranking	Metadata Element Name	Mean	SD
1	Labs used in the Inquiry Learning Space	4,41	0,73
2	Inquiry Learning Space Title	4,35	0,86
3	Subject domains that the Inquiry Learning Space addresses	4,13	0,97
4	Inquiry Learning Space Available Languages	4,09	1,12
5	Keywords	4,03	1,01
6	Organizational Requirements needed to use the Inquiry Learning Space	4,10	1,03
7	Age Range that the Inquiry Learning Space can be used	4,06	1,02
8	Educational objectives addressed by the Inquiry Learning Space	3,96	0,98
9	Status of the Inquiry Learning Space	4,04	1,16
10	Additional materials included in the Inquiry Learning Space	4,02	1,00
11	Students' prior knowledge needed to use the Inquiry Learning Space	3,92	1,11
12	Average learning time of the Inquiry Learning Space	3,92	1,15
13	Level of interaction of the Inquiry Learning Space	3,89	1,01
14	The pedagogical scenario used in the Inquiry Learning Space	3,85	1,10
15	The Big Ideas of Science that the Inquiry Learning Space addresses	3,78	1,13
16	Level of difficulty of the Inquiry Learning Space	3,84	1,12
17	Inquiry Learning Space Access rights	3,71	1,29
18	Inquiry Learning Space Owner and Contributors	3,36	1,38

It is worth noticing that no elements received very low score, in fact, the lowest score in average was 3.07 - corresponding to element **"*Inquiry Learning Space Owner and Contributors*"** (for the context of use related to general search for ILSs in the Go-Lab repository), which is still on the positive side of the likert scale. Thus, an overall indication could be that **none of the metadata elements can be regarded as non-important** and our proposed metadata model can be considered valid and useful for the Go-Lab science teachers. Nevertheless, besides this general indication, it is worth further analyzing the ranking of the metadata elements based on their average score for each context of use. More specifically, as we can notice from Table 16, 17 and 18, there are some elements that highly ranked across all three contexts of use. These elements are (as presented in Table 20): (a) **"*ILS Title*"** (1-1-2: ranked 1st for the context of use related to making a general search for ILSs in the Go-Lab Repository, 1st for the context of use that was related to filtering search results of ILSs in the Go-Lab Repository and 2nd for the context of use that was related to viewing the preview page of an ILS in the Go-Lab Repository), (b) **"*Labs used in the ILS*"** (6-5-1), (c) **"*Subject Domain*"** (2-3-3), (d) **"*Keywords*"** (3-2-5), (e) **"*ILS available Languages*"** (4-4-4) and (f) **"*Age Range*"** (5-6-7).

Table 20: Highly Ranked ILS Metadata Elements across all three Contexts of Use

No	Metadata Element	General Search (Average Value - Rank)	Filtering (Average Value - Rank)	Preview Page (Average Value - Rank)
1	ILS Title	4,36 (1)	4,37 (1)	4,35 (2)
2	Subject Domain	4,29 (2)	4,25 (3)	4,13 (3)
3	Keywords	4,23 (3)	4,36 (2)	4,03 (5)
4	Labs used in the ILS	4,05 (6)	4,23 (5)	4,41 (1)
5	ILS available Languages	4,15 (4)	4,24 (4)	4,09 (4)
6	Age Range	4,13 (5)	4,19 (6)	4,06 (7)

Based on these results presented in Table 20), we can identify that:

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

On the other hand, the elements that ranked low across all three contexts were the following (as presented in

Table 21): (a) **"*ILS Owner and Contributors*"** (18-18-18), (b) **"*ILS Access Rights*"** (17-17-17), (c) **"*The pedagogical scenario used in the ILS*"** (12-16-14) and (d) **"*Level of Difficulty*"** (16-9-16).

Table 21: Lowest Ranked ILS Metadata Elements across all three Contexts of Use

No	Metadata Element	General Search (Average Value - Rank)	Filtering (Average Value - Rank)	Preview Page (Average Value - Rank)
1	ILS Owner and Contributors	3,07 (18)	3,19 (18)	3,36 (18)
2	ILS Access Rights	3,44 (17)	3,59 (17)	3,71 (17)
3	The pedagogical scenario used in the ILS	3,61 (12)	3,868 (16)	3,85 (14)
4	Level of Difficulty	3,47 (16)	3,89 (9)	3,84 (16)

Nevertheless, the average scores (as presented in

Table 21) of these metadata did not call for an automatic elimination from the list of metadata elements of our proposed metadata model. Moreover, we can identify that it makes sense that "*ILS Owner and Contributors*" and "*ILS Access Rights*" metadata elements are at the bottom of the ranking list since they do not offer rich information in order to facilitate the selection of a certain ILS, but they are essential in order to give credits to the owner of the offered ILS and to clarify the access rights in order to avoid legal issues.

Finally, it should be mentioned that the element **"*Big Ideas of Science*"** has received an average score of 3,74 across all three contexts and it can be considered medium ranking among other metadata elements. More specifically, the element **"*Big Ideas of Science*"** was 9th for the context of use related to making a general search for ILSs in the Go-Lab Repository, 15th for the context of use that was related to filtering search results of ILSs in the Go-Lab Repository and 15th for the context of use that was related to viewing the preview page of an ILS in the Go-Lab Repository. Nevertheless, as already presented in chapter 4, participants were not initially familiar with this concept and after being informed about this concept, they have considered this element as important for organizing online labs and ILSs in the Go-Lab repository.

7 Extending the Go-Lab Taxonomy

In deliverable D2.1, we presented the taxonomy that was adopted to characterize the online labs and ILSs that are stored in the Go-Lab repository. This taxonomy covered Science and Mathematics subject domains. However, in order to cover the full spectrum of STEM fields, a similar taxonomy was needed for Technology and Engineering (T&E) subject domains. Next, we present the process that was followed for extending the Go-Lab Taxonomy to cover the Technology and Engineering subject domains. In order to define an appropriate taxonomy for T&E, we reviewed web-based repositories that use similar taxonomies for classifying and storing T&E educational resources. Our review criteria were the following:

- The taxonomy should be appropriate to characterize educational resources for school education (primary and secondary), since Go-Lab Project aims to provide online labs and ILSs for this particular educational level.
- The taxonomy should be detailed and it should be elaborated in various sub-levels. This will be able to provide to the teachers of the Go-Lab repository to navigate smoothly and effectively through the available T&E online labs and ILSs.

Based on the aforementioned review criteria, we identified two (2) web-based repositories, which were incorporating suitable taxonomies for classifying educational resources for School Technology Education.

Table 22 presents the identified repositories and the taxonomies that they use, as well as the number of educational resources classified with these taxonomies compared with the number of educational resources stored in the repositories.

Table 22: Web-based Repositories that Incorporate Taxonomies for School Technology Education

Repository Title	Technology Taxonomy Levels		
	Level 1	Level 2	Level 3
KLasCement - http://goo.gl/KqGEiw	Technology	Vehicle	-
		Construction - Architecture	-
		Electricity - Electronics	-
		Glass -Glass Technology	-
		Wood	-
		Hairdresser	-
		Cooling and Heating	-
		Maritime Studies	-
		Mechanics	-
		Metal	-
		Technological Education	-
		Textile	-
		Science and Technology Drawing	-
Photodentro Videos - http://goo.gl/CJqk2c	Technology	Design	3d Views of Objects
			View Design
			Design Instruments
			Aspect Design
		Industry	Automation Systems
			Roles
		Production	Profit
			Products
			Primary Sector
			Rates
			System
			Technological Evolution
		Internet	Information search
		Model Construction	Google Earth

As we can notice from

Table 22, both presented taxonomies provide an in-depth analysis of the Technology Subject Domain in various levels. Moreover, we can notice that each taxonomy is complimentary to the other one, since there are no duplicates among them. However, while the vast majority of their terms is appropriate for classifying educational resources for Technology Education, there are some elements that seem to not fit our needs. More specifically, regarding the KlasCement repository, there are two terms namely “hairdresser” and “textile” that mainly target vocational education and they are not appropriate for the scope of Go-Lab project. Moreover, regarding the Photodentro Videos repository, there is a term namely “Google Earth”, which refers to a tool and it might be inappropriate for the Go-Lab taxonomy. Finally, we noticed that some elements of Photodentro’s taxonomy should be included under a more general term of KlasCement Taxonomy. For instance, the “model construction” term of Photodentro’s Taxonomy should be under the term “Construction-Architecture” of KlasCement’s Taxonomy.

As a result, we decided to merge and rearrange the taxonomies presented in

Table 22 and replace the terms that are beyond the scope of the Go-Lab project with more appropriate ones. Table 23, presents our proposed taxonomy for School Technology Education.

Table 23: The Proposed Taxonomy for School Technology Education

Technology Taxonomy Levels		
Level 1	**Level 2**	**Level 3**
Technology	A. Construction - Architecture	i. Model Construction
		ii. Metal
		iii. Wood
		iv. Glass - Glass Technology
	B. Design	i. 3D Views of Objects
		ii. View Design
		iii. Design Instruments
		iv. Science and Technology Drawing
		v. Aspect Design
	C. Electricity - Electronics	i. Electronic circuits
		ii. Programmable electronics
		iii. Control devices
		iv. Sensors
	D. Industry	i. Automation Systems
		ii. Renewable energy
		iii. Enviromental technology
		iv. Roles
	E. Internet	i. Information search
		ii. Digital Information
	F. Mechanics	i. Cooling and Heating
		ii. Vehicle
	G. Production	i. Profit
		ii. Products
		iii. Primary Sector
		iv. Rates
		v. System
		vi. Technological Evolution
	H. Computer Science and Technology	i. Programming languages
		ii. Digital System Representation
		iii. Mathematical models
		iv. Data representation and analysis

The next step was to identify web-based repositories that incorporate suitable taxonomies for classifying educational resources for School Engineering Education. Based on the aforementioned review criteria, we identified two web-based repositories. Table 23 presents the identified repositories and the taxonomies that they use, as well as the number of educational resources classified with these taxonomies compared with the number of educational resources stored in the repositories.

Table 24: Web-based Repositories that Incorporate Taxonomies for School Engineering Education

Repository Title	Engineering Taxonomy Levels		
	Level 1	Level 2	Level 3
The Orange Grove - http://goo.gl/IexSvz	Engineering	Aeronautical Science	-
		Biomedical Engineering	-
		Chemical/Nuclear Engineering	-
		Computer Math Engineering	-
		Computing Technologies	-
		Drafting: Engineering Technologies	-
		Electrical Engineering	-
		Engineering Technologies	-
		Industrial Engineering	-
		Mechanical Engineering	-
		Precision Metals Technology	-
		Transportation & Logistics	-
		Architecture	-
		Building Construction	-
		Civil/Environmental Engineering	-
		Computer Science	-
		Digital Media	-
		Electronic Technology	-
		Engineering: General/Support	-
		Heat./Vent/AC/Refrig.: Tech./Trades	-
		Landscape Architecture	-
		Mechanics	-
		Surveying & Mapping	-
Banco Internacional de Objetos Educacionais (BIOE) – http://goo.gl/KUBQW0	Engineering	A. Aerospace Engineering	i. Satellites and Aerospace Devices
		B. Biomedical Engineering	i. Bioengineering
			ii. Medical Engineering
		C. Civil Engineering	i. Construction
			ii. Hydraulic Engineering
			iii. Structures
			iv. Building Installations
			v. Construction Materials and Components
			vi. Structural Mechanics

Repository Title	Engineering Taxonomy Levels		
	Level 1	Level 2	Level 3
			vii. Mechanical Soil
			viii. Construction Processes
		D. Mining Engineering	i. Mineral Research
		E. Production Engineering	i. Game Theory
		F. Transport Engineering	i. Vehicles and Control Equipment
		G. Electrical Engineering	i. Electrical Circuits, Magnetic and Electronic
			ii. Electronic Circuits
			iii. Magnetic circuits, magnetism, electromagnetism
			iv. Generation of Electricity
			v. Electrical Building Services and Industrial Facilities
			vi. Materials Conductors
			vii. Electrical Materials
			viii. Electrical Measurements, Magnetic and Electronic; Instrumentation
			ix. Magnetic Measurements
			x. Telecommunications
		H. Mechanical Engineering	i. Energy use
			ii. Thermal Engineering
			iii. Machinery, Engines and Equipment
			iv. Machines Projects
		I. Naval and Ocean Engineering	i. Marine and Ocean Structures
		J. Chemical Engineering	i. Oils
			ii. Treatment and Utilization of Wastes
		K. Sanitary Engineering	i. Water Resources
			ii. Solid Waste, Domestic and Industrial
			iii. Environmental Sanitation
			iv. Water Supply and Waste water Treatment

As we can notice from Table 24, the taxonomy adopted by the Orange Grove repository is not elaborated in different levels. Moreover, only a small portion of stored educational resources are classified based on this taxonomy. On the other hand, the taxonomy adopted by the BIOE repository provides an adequate level of elaboration into various sub-levels. Moreover, an adequate fraction of the total educational resources stored in the repository have been classified based on this taxonomy. As a result, we decided to adopt for the Go-Lab Project the Engineering taxonomy of the BIOE repository.

Table 25: The Proposed Taxonomy for School Engineering Education

Engineering Taxonomy Levels		
Level 1	**Level 2**	**Level 3**
Engineering	A. Aerospace Engineering	i. Satellites and Aerospace Devices
	B. Biomedical Engineering	i. Bioengineering
		ii. Medical Engineering
	C. Civil Engineering	i. Construction
		ii. Hydraulic Engineering
		iii. Structures
		iv. Building Installations
		v. Construction Materials and Components
		vi. Of Structural Mechanics
		vii. Mechanical Soil
		viii. Construction Processes
	D. Mining Engineering	i. Mineral Research
	E. Production Engineering	i. Game Theory
	F. Transport Engineering	i. Vehicles and Control Equipment
	G. Electrical Engineering	i. Electrical Circuits, Magnetic and Electronic
		ii. Electronic Circuits
		iii. Magnetic circuits, magnetism, electromagnetism
		iv. Generation of Electricity
		v. Electrical Building Services and Industrial Facilities
		vi. Materials Conductors
		vii. Electrical Materials
		viii. Electrical Measurements, Magnetic and Electronic; Instrumentation
		ix. Magnetic Measurements
		x. Telecommunications
	H. Mechanical Engineering	i. Energy use
		ii. Thermal Engineering
		iii. Machinery, Engines and Equipment
		iv. Machines Projects
	I. Naval and Ocean Engineering	i. Marine and Ocean Structures
	J. Chemical Engineering	i. Oils
		ii. Treatment and Utilization of Wastes
	K. Sanitary Engineering	i. Water Resources
		ii. Solid Waste, Domestic and Industrial
		iii. Environmental Sanitation
		iv. Water Supply and Waste water Treatment

8 Conclusions and Next Steps

The Go-Lab inventory currently includes 161 online labs out of which 13 were integrated during the first year of the project and 35 during the second and 118 during the third year of the project. This demonstrates that the mechanism, which has been set by the consortium for the continuous population of the Go-Lab repository is very successful and it has by far exceeded the initial planned sample to support the large scale implementation activities. The consortium has already established cooperation with more external lab owners and it is expected that the Go-lab repository will be populated with more online labs during the 4th year of the project. Moreover, appropriate mechanisms have been set-up for enabling lab owners to receive feedback from the Go-Lab teacher's community regarding the usage and the efficiency of their online labs. These are important actions for the sustainability of the Go-Lab repository after the end of the project.

Moreover, the consortium has performed an extended validation exercise with users in order to assess the potential impact of the proposed online labs and ILSs classification scheme in the Go-Lab repository. The main findings are:

- The updated Go-Lab Big Ideas of Science set is very close to teachers and teachers' trainers notion on Big Ideas and it has received even higher scores compared to the initial set. Based on our research, we concluded that no further adaptations needed to be made. In terms of presentation within the repository, users can easily use the Big Ideas of Science to find relevant activities and labs. However certain improvement could be made to make them even more prominent.
- The Go-Lab ILSs metadata schema has been validated by the Go-Lab teachers and no further adaptations were requested. The Go-Lab ILS metadata schema includes 21 metadata fields.

Next steps include further extending the Go-Lab inventory with more online labs from external labs owners focusing especially on covering extensively all STEM subjects.

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Annex A: Questionnaires used in the Validation Workshops of the Big Ideas of Science

A1: Pre Questionnaire

Background information

Gender:
- ☐ Male
- ☐ Female

Years of teaching experience:
- ☐ 0 – 5 years
- ☐ 6 – 10 years
- ☐ 11 – 15 years
- ☐ >15 years

Education:
- ☐ BSc (bachelor's degree)
- ☐ MSc (master degree)
- ☐ Phd (doctorate)
- ☐ Other……………………………………………………………………..

I am teaching students:
- ☐ Less than 6 years old
- ☐ 6-9 years old
- ☐ 9-12 years old
- ☐ 12-15 years old
- ☐ 15-18 years old
- ☐ Older than 18
- ☐ Other……………………………………………………………..

My teaching area is:
- ☐ Physics
- ☐ Biology
- ☐ Chemistry
- ☐ Geography
- ☐ Environmental Sciences
- ☐ Other…………………………………………

Are you a teachers' trainer?
- ☐ Yes
- ☐ No

1. **Are you familiar with the concept of the “Big Ideas of Science”?**
   - ☐ Not familiar at all
   - ☐ I have only heard a little about it
   - ☐ I am quite familiar
   - ☐ I am very well acquainted with the “Big Ideas of Science”

2. **Which of the following definitions do you believe describes best the “Big Ideas of Science”?**
   - ☐ A set of ideas that briefly outline science’s greatest achievements and discoveries.
   - ☐ 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 set of concepts that outline how science works and what principles (ethical, social, economic and political implications) it is submitted to.
   - ☐ A set of proposals that demonstrate to teachers how to teach science in the most successful and efficient way.

3. **When teaching any given science subject in your class; how often do you try to connect it to students’ everyday life and the world around us?**
   - ☐ Never
   - ☐ Sometimes, but not very often
   - ☐ As often as I can
   - ☐ Always

4. **When teaching any given science subject in your class; how often do you try to connect it to other subjects that students have been taught in the present year or past years?**
   - ☐ Never
   - ☐ Sometimes, but not very often
   - ☐ As often as I can
   - ☐ Always

5. **How important do you believe it is to connect the science subjects taught in school with everyday life and the world around us?**
   - ☐ Not important at all
   - ☐ A little important
   - ☐ Very important
   - ☐ I think it is absolutely necessary

6. **How important do you believe it is to connect the science subjects taught in school with other subjects that students have been taught in the present year or past years?**
   - ☐ Not important at all
   - ☐ A little important
   - ☐ Very important
   - ☐ I think it is absolutely necessary

A2: Post Questionnaire

Are you a teachers' trainer?

☐ Yes
☐ No

1. **What are the Big Ideas of science according to you?**

___

2. **Which of the two sets is closer to the Big Ideas you thought?**[4]
   - ☐ Set A
   - ☐ Set B
   - ☐ None of the two
   - ☐ Both are very close

3. **Which of the two sets is more appropriate for your students according to your opinion?**
   - ☐ Set A
   - ☐ Set B
   - ☐ None of the two

   Please explain briefly why:

   ___

4. **Check again set A. Is there something missing, something unnecessary or something you don't like?**

   ___

5. **Do what degree do you find set A to be satisfying?**

	1	2	3	4	5	
Not satisfying at all						Very satisfying

6. **Do you have any other comments?**

   ___

   ___

7. **How important do you regard "Big Ideas of Science" to be when it comes to teaching science?**

	1	2	3	4	5	
Not important at all						Very important

[4] Set A corresponds to the Go-Lab set and Set B corresponds to Harlen's set. Sets were labeled A and B so as to avoid influencing participants' opinion.

8. So you think that a recommendation system using the "Big Ideas of Science would be useful?

	1	2	3	4	5	
Not useful at all						Very useful

A3: Usability Test

GoLabz main page

Let's say you want to find a lab to teach your students about energy. Where would you click on the page?

____

How did you navigate in the page you clicked?

____

Now try to make a query using the Big Ideas of Science. Where did you click in order to do that?

____

Preview page of the lab

Can you now find another lab that has a common Big Idea? How did you find it?

____

____

Big Ideas of Science tab

How would you characterize this page?

____

____

Do you like the presentation of the BI?

____

____

What purpose do you believe it serves?

____

____

Annex B - Questionnaire for Validating the Metadata Model for Go-Lab Inquiry Learning Spaces

Metadata elements describe the different characteristics and attributes of an Inquiry Learning Space, e.g. the title, the author, the date the subject domain etc. and aims to help teachers to easily select and retrieve Inquiry Learning Spaces from the Go-Lab Repository (GoLabz- http://www.golabz.eu/) according to their pedagogical needs.

Imagine you are in the Go-Lab repository and you wish to make a search for Inquiry Learning Spaces.

Please indicate how important you believe each element in the table below is in terms of using them to:

a) make a new search in the Go-Lab repository for an Inquiry Learning Space
b) further refine a search you made in the Go-Lab repository for an Inquiry Learning Space
c) To be informed about details of the Inquiry Learning Space via its preview page?

Background Information	
Gender	☐ Male ☐ Female
Years of Teaching Experience	☐ 0–5 years ☐ 5–10 years ☐ 10–15 years ☐ >15 years
Level of Education	☐ BSc (Bachelor Degree) ☐ MSc (Master Degree) ☐ PhD (Doctorate) ☐ Other:
ICT Knowledge	☐ Yes ☐ No
ICT Usage During Teaching	☐ Yes ☐ No

Questions about Inquiry Learning Spaces' metadata						
No	**Metadata Element**	**1** *(Low Importance)*	**2**	**3**	**4**	**5** *(High Importance)*
1	Inquiry Learning Space Title					
2	Keywords					

3	Inquiry Learning Space Available Languages					
4	Labs used in the Inquiry Learning Space					
5	Age Range that the Inquiry Learning Space can be used					
6	The Big Ideas of Science that the Inquiry Learning Space addresses					
7	Subject domains that the Inquiry Learning Space addresses					
8	Educational objectives addressed by the Inquiry Learning Space					
9	The pedagogical scenario used in the Inquiry Learning Space					
10	Status of the Inquiry Learning Space					
11	Inquiry Learning Space Access rights					
12	Level of difficulty of the Inquiry Learning Space					
13	Level of interaction of the Inquiry Learning Space					
14	Students' prior knowledge needed to use the Inquiry Learning Space					
15	Additional materials included in the Inquiry Learning Space					
16	Average learning time of the Inquiry Learning Space					
17	Inquiry Learning Space Owner and Contributors					
18	Organization Requirements needed to use the Inquiry Learning Space					

Any additional comments?

Annex C – List of Online Labs Added to the Go-Lab Inventory (Year 3)

No	Online Lab Title	Online Lab URL	Go-Lab Repository URL
1	**Free Fall in Vacuum**	http://www.remlabnet.eu/?page=exp&id=14	http://www.golabz.eu/lab/free-fall-vacuum
2	**ARCHIMEDES' LAW**	http://www.remlabnet.eu/?page=exp&id=9	http://www.golabz.eu/lab/archimedes%E2%80%99-law
3	**Sun Shadow Visualizer**	https://dl.dropboxusercontent.com/u/29419116/Soeren%20Werneburg.html	http://www.golabz.eu/lab/sun-shadow-visualizer
4	**Simple Pendulum**	http://www.remlabnet.eu	http://www.golabz.eu/lab/simple-pendulum
5	**What is Pressure?**	http://lab.concord.org/embeddable.html#interactives/sam/gas-laws/2-what-is-pressure.json	http://www.golabz.eu/lab/what-pressure
6	**The Volume-Pressure Relationship**	http://lab.concord.org/embeddable.html#interactives/sam/gas-laws/3-volume-pressure-relationship.json	www.golabz.eu/lab/volume-pressure-relationship
7	**The Temperature-Volume Relationship**	http://lab.concord.org/embeddable.html#interactives/sam/gas-laws/4-temperature-volume-relationship.json	http://www.golabz.eu/lab/temperature-volume-relationship
8	**The Temperature-Pressure Relationship**	http://lab.concord.org/embeddable.html#interactives/sam/gas-laws/5-temperature-pressure-relationship.json	http://www.golabz.eu/lab/temperature-pressure-relationship
9	**Seeing Intermolecular Attractions**	http://lab.concord.org/embeddable.html#interactives/sam/intermolecular-attractions/1-introduction.json	http://www.golabz.eu/lab/seeing-intermolecular-attractions
10	**Polarity and Attractive Strength**	http://lab.concord.org/embeddable.html#interactives/sam/intermolecular-attractions/4-strengthening-dipole-dipole-attractions.json	www.golabz.eu/lab/polarity-and-attractive-strength
11	**Phase Change**	http://lab.concord.org/embeddable.html#interactives/sam/phase-change/6-phase-changes-caused-by-energy-input.json	http://www.golabz.eu/lab/phase-change
12	**Oil and Water**	http://lab.concord.org/embeddable.html#interactives/sam/intermolecular-attractions/3-1-oil-and-water.json	http://www.golabz.eu/lab/oil-and-water
13	**Molecular View of a Solid**	http://lab.concord.org/embeddable.html	http://www.golabz.eu/lab/mole

		#interactives/sam/phase-change/4-solids.json	cular-view-solid
14	**Molecular View of a Liquid**	http://lab.concord.org/embeddable.html #interactives/sam/phase-change/3-liquids.json	http://www.golabz.eu/lab/mole cular-view-liquid
15	**Molecular View of a Gas**	http://lab.concord.org/embeddable.html #interactives/sam/phase-change/2-two-types-of-gases.json	http://www.golabz.eu/lab/mole cular-view-gas
16	**Factors Affecting London Dispersion Attractions**	http://lab.concord.org/embeddable.html #interactives/sam/intermolecular-attractions/5-strengthening-london-dispersion-attraction.json	http://www.golabz.eu/lab/facto rs-affecting-london-dispersion-attractions
17	**Diffusion of a Drop**	http://lab.concord.org/embeddable.html #interactives/sam/diffusion/1-dropping-dye-on-click.json	http://www.golabz.eu/lab/diffu sion-drop
18	**Diffusion and Temperature**	http://lab.concord.org/embeddable.html #interactives/sam/diffusion/2-temperature.json	www.golabz.eu/lab/diffusion-and-temperature
19	**Diffusion and Molecular Mass**	http://lab.concord.org/embeddable.html #interactives/sam/diffusion/3-mass.json	http://www.golabz.eu/lab/diffu sion-and-molecular-mass
20	**Diffusion Across a Semipermeable Membrane**	http://lab.concord.org/embeddable.html #interactives/sam/diffusion/4-semipermeable.json	http://www.golabz.eu/lab/diffu sion-across-semipermeable-membrane
21	**Protein Folding**	http://lab.concord.org/embeddable.html #interactives/samples/5-amino-acids.jsonc	http://www.golabz.eu/lab/prote in-folding
22	**Mutations**	http://lab.concord.org/embeddable.html #interactives/sam/DNA-to-proteins/4-mutations.json	http://www.golabz.eu/lab/muta tions
23	**Modeling Translation**	http://lab.concord.org/embeddable.html #interactives/sam/DNA-to-proteins/3-modeling-translation.json	http://www.golabz.eu/lab/mod eling-translation
24	**Modeling Transcription**	http://lab.concord.org/embeddable.html #interactives/sam/DNA-to-proteins/2-modeling-transcription.json	http://www.golabz.eu/lab/mod eling-transcription
25	**DNA to Protein**	http://lab.concord.org/embeddable.html #interactives/sam/DNA-to-proteins/1-dna-to-protein.json	http://www.golabz.eu/lab/dna-protein
26	**Where Is the Most Heat Lost?**	http://lab.concord.org/embeddable.html #interactives/energy2d/htb/S6B1.json	http://www.golabz.eu/lab/wher e-most-heat-lost

27	**Vertical Temperature Gradients**	http://lab.concord.org/embeddable.html#interactives/energy2d/htb/S6C1.json	http://www.golabz.eu/lab/vertical-temperature-gradients
28	**Sunlight, Infrared, CO2 and the Ground**	http://lab.concord.org/embeddable.html#interactives/sam/light-matter/sun-on-ground.json	http://www.golabz.eu/lab/sunlight-infrared-co2-and-ground
29	**Metal Forces**	http://lab.concord.org/embeddable.html#interactives/sam/phase-change/5-interatomic-interactions-and-states.json	www.golabz.eu/lab/metal-forces
30	**Intermolecular Attractions and State of Matter**	http://lab.concord.org/embeddable.html#interactives/sam/phase-change/5-interatomic-interactions-and-states.json	http://www.golabz.eu/lab/intermolecular-attractions-and-state-matter
31	**Hydrogen Bonds**	http://lab.concord.org/embeddable.html#interactives/sam/intermolecular-attractions/6-hydrogen-bonds-a-special-type-of-attraction.json	http://www.golabz.eu/lab/hydrogen-bonds
32	**Exploring Electron Properties**	http://lab.concord.org/embeddable.html#interactives/interactions/electronProperties.json	http://www.golabz.eu/lab/exploring-electron-properties
33	**Convection: The Stack Effect**	http://lab.concord.org/embeddable.html#interactives/energy2d/htb/S4D1.json	http://www.golabz.eu/lab/convection-stack-effect
34	**Mach Zehnder 5**	http://shindig2.epfl.ch/gadgets/ifr?nocache=1&url=http://shindig2.epfl.ch/gadget/go-lab/lab/mach-zehnder/AdaptablePath.xml	http://www.golabz.eu/lab/mach-zehnder-5
35	**Convection: Blowing Wind**	http://lab.concord.org/embeddable.html#interactives/energy2d/htb/S4E1.json	http://www.golabz.eu/lab/convection-blowing-wind
36	**Comparing Dipole-Dipole to London Dispersion**	http://lab.concord.org/embeddable.html#interactives/sam/intermolecular-attractions/2-comparing-dipole-dipole-to-london-dispersion.json	http://www.golabz.eu/lab/comparing-dipole-dipole-london-dispersion
37	**Comparing Attractive Forces**	http://lab.concord.org/embeddable.html#interactives/interactions/comparing-attractive-forces.json	http://www.golabz.eu/lab/comparing-attractive-forces
38	**Charged and Neutral Atoms**	http://lab.concord.org/embeddable.html#interactives/samples/3-100-atoms.json	http://www.golabz.eu/lab/charged-and-neutral-atoms
39	**Mach Zehnder 4**	http://go.epfl.ch/machzehnder4	http://www.golabz.eu/lab/mach-zehnder-4
40	**Mach Zehnder 3**	http://go.epfl.ch/machzehnder3	http://www.golabz.eu/lab/mac

			h-zehnder-3
41	**Ceramic Forces**	http://lab.concord.org/embeddable.html#interactives/visual/recycling/1-ceramicforces.json	http://www.golabz.eu/lab/ceramic-forces
42	**Boiling Point**	http://lab.concord.org/embeddable.html#interactives/sam/intermolecular-attractions/3-2-boiling-point-and-solubility.json	http://www.golabz.eu/lab/boiling-point
43	**Mach Zehnder 2**	http://go.epfl.ch/machzehnder2	http://www.golabz.eu/lab/mach-zehnder-2
44	**Reactants, Products and Leftovers**	http://phet.colorado.edu/sims/html/reactants-products-and-leftovers/latest/reactants-products-and-leftovers_en.html	http://www.golabz.eu/lab/reactants-products-and-leftovers
45	**Molecule Shapes: Basics**	http://phet.colorado.edu/sims/html/molecule-shapes-basics/latest/molecule-shapes-basics_en.html	http://www.golabz.eu/lab/molecule-shapes-basics
46	**Molecule Shapes**	http://phet.colorado.edu/sims/html/molecule-shapes/latest/molecule-shapes_en.html	http://www.golabz.eu/lab/molecule-shapes
47	**Balancing Act**	http://phet.colorado.edu/sims/html/balancing-act/latest/balancing-act_en.html	www.golabz.eu/lab/balancing-act
48	**Mach Zehnder 1**	http://go.epfl.ch/machzehnder1	http://www.golabz.eu/lab/mach-zehnder-1
49	**Density and buoyancy**	http://phet.colorado.edu/sims/density-and-buoyancy/density_en.html	http://www.golabz.eu/lab/density-and-buoyancy
50	**Big Construction and circuits analysis behavior inside**	http://www-tc.pbs.org/wgbh/buildingbig/lab/swf/forces.swf	http://www.golabz.eu/lab/big-construction-and-circuits-analysis-behavior-inside
51	**LXI-VISIR Deusto: AC circuits**	https://weblab.deusto.es/weblab/client/#page=experiment&exp.category=Visir%20experiments&exp.name=Fisica-3	http://www.golabz.eu/lab/lxi-visir-deusto-ac-circuits
52	**LXI-VISIR Deusto: DC circuits**	https://weblab.deusto.es/weblab/client/?locale=en#page=experiment&exp.category=Visir%20experiments&exp.name=Fisica-1	http://www.golabz.eu/lab/lxi-visir-deusto-dc-circuits
53	**The Pauli Principle: Quantum particles in an infinite square well**	http://www.st-andrews.ac.uk/physics/quvis/simulations_html5/sims/Particles-infwell/particles-infwell.html	http://www.golabz.eu/lab/pauli-principle-quantum-particles-infinite-square-well

54	**Interferometer experiments with single photons**	http://www.st-andrews.ac.uk/physics/quvis/simulations_html5/sims/SinglePhotonLab/SinglePhotonLab.html	http://www.golabz.eu/lab/interferometer-experiments-single-photons
55	**Probabilistic analysis of a mass-spring system**	http://www.st-andrews.ac.uk/physics/quvis/simulations_html5/sims/ClassicalOscillator/ClassicalOscillator.html	http://www.golabz.eu/lab/probabilistic-analysis-mass-spring-system
56	**Color Vision**	https://phet.colorado.edu/sims/html/color-vision/latest/color-vision_en.html	http://www.golabz.eu/lab/color-vision
57	**Balloons and Static Electricity**	https://phet.colorado.edu/sims/html/balloons-and-static-electricity/latest/balloons-and-static-electricity_en.html	http://www.golabz.eu/lab/balloons-and-static-electricity
58	**Graphing Lines**	https://phet.colorado.edu/sims/html/graphing-lines/latest/graphing-lines_en.html	http://www.golabz.eu/lab/graphing-lines
59	**Build an Atom**	https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html	http://www.golabz.eu/lab/build-atom
60	**Fraction Matcher**	https://phet.colorado.edu/sims/html/fraction-matcher/latest/fraction-matcher_en.html	http://www.golabz.eu/lab/fraction-matcher
61	**pH Scale: Basics**	https://phet.colorado.edu/sims/html/ph-scale-basics/latest/ph-scale-basics_en.html	http://www.golabz.eu/lab/ph-scale-basics
62	**Concentration**	https://phet.colorado.edu/sims/html/concentration/latest/concentration_en.html	http://www.golabz.eu/lab/concentration
63	**Faraday's law**	https://phet.colorado.edu/sims/html/faradays-law/latest/faradays-law_en.html	http://www.golabz.eu/lab/faradays-law
64	**John Travoltage**	https://phet.colorado.edu/sims/html/john-travoltage/latest/john-travoltage_en.html	http://www.golabz.eu/lab/john-travoltage
65	**Ohm's law**	http://phet.colorado.edu/sims/html/ohms-law/latest/ohms-law_en.html	http://www.golabz.eu/lab/ohms-law
66	**Forces and Motion: Basics**	https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html	http://www.golabz.eu/lab/forces-and-motion-basics
67	**Energy Skate Park: Basics**	https://phet.colorado.edu/sims/html/energy-skate-park-basics/latest/energy-	http://www.golabz.eu/lab/energy-skate-park-basics

		skate-park-basics_en.html	
68	**Windmill Lab**	http://weblab.ieec.uned.es/golab/ajirizar/uiEolic/	http://www.golabz.eu/lab/windmill-lab
69	**Electromagnetic field energies in capacitors and inductors**	http://demonstrations.wolfram.com/ElectromagneticFieldEnergiesInCapacitorsAndInductors/	http://www.golabz.eu/lab/electromagnetic-field-energies-capacitors-and-inductors
70	**Friction Lab**	http://web.educastur.princast.es/proyectos/fisquiweb/Dinamica/rozamiento.htm	http://www.golabz.eu/lab/friction-lab
71	**Boyle's Law experiments**	http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/gaslaw/boyles_law_graph.html	http://www.golabz.eu/lab/friction-lab
72	**VCISE: Drosophila melanogaster genetics experiment**	http://www.sciencecourseware.org/vcise/drosophila/	http://www.golabz.eu/lab/boyles-law-experiments
73	**Archimedes' Principle**	https://www.weblab.deusto.es/weblab/client/#page=experiment&exp.category=Aquatic%20experiments&exp.name=archimedes	http://www.golabz.eu/lab/archimedes-principle
74	**Solar Lab**	http://weblab.ieec.uned.es/golab/ajirizar/uiSolar/	http://www.golabz.eu/lab/solar-lab
75	**Electromagnetic Crane Laboratory**	http://graasp.eu/applications/55a53c215f8ed52f2acaf765	http://www.golabz.eu/lab/electromagnetic-crane-laboratory
76	**Robotic Arm laboratory**	http://graasp.eu/applications/54d8ad0f17cf888ac8d6af04	http://www.golabz.eu/lab/robotic-arm-laboratory
78	**Gas Laws**	http://create.nyu.edu/dream/login.php?play=simGL	http://www.golabz.eu/lab/gas-laws
79	**Phase Change II**	http://create.nyu.edu/dream/login.php?play=simPC2	http://www.golabz.eu/lab/phase-change-ii
80	**Phase Change I**	http://create.nyu.edu/dream/login.php?play=simPC1	http://www.golabz.eu/lab/phase-change-i
81	**Kinetic Molecular Theory II**	http://create.nyu.edu/dream/login.php?play=simKMT2	http://www.golabz.eu/lab/kinetic-molecular-theory-ii
82	**The color of the light**	http://62.204.201.213/German/ledRGB/led_rgb.html	http://www.golabz.eu/lab/color-light
83	**Kinetic Molecular Theory**	http://create.nyu.edu/dream/login.php?play=simKMT1	http://www.golabz.eu/lab/kinetic-molecular-theory
84	**Diffusion**	http://create.nyu.edu/dream/login.php?play=simDiff	http://www.golabz.eu/lab/diffusion

85	**Balancing Chemical Equations**	https://phet.colorado.edu/sims/html/balancing-chemical-equations/latest/balancing-chemical-equations_en.html	http://www.golabz.eu/lab/balancing-chemical-equations
86	**Beer's Law Lab**	https://phet.colorado.edu/sims/html/beers-law-lab/latest/beers-law-lab_en.html	http://www.golabz.eu/lab/beers-law-lab
87	**Resistance in a Wire**	https://phet.colorado.edu/sims/html/resistance-in-a-wire/latest/resistance-in-a-wire_en.html	http://www.golabz.eu/lab/resistance-wire
88	**Under Pressure**	http://phet.colorado.edu/sims/html/under-pressure/latest/under-pressure_en.html	http://www.golabz.eu/lab/under-pressure
89	**Friction**	http://phet.colorado.edu/sims/html/friction/latest/friction_en.html	http://www.golabz.eu/lab/friction
90	**Wave on a String**	phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html	http://www.golabz.eu/lab/wave-string
91	**Interactive METEOSAT**	http://www.asrc.ro/imeteosat_beta/	http://www.golabz.eu/lab/interactive-meteosat
92	**Star in a Box**	http://lcogt.net/siab/	http://www.golabz.eu/lab/star-box
93	**Worldwide Telescope**	http://www.worldwidetelescope.org/webclient/default.aspx	http://www.golabz.eu/lab/worldwide-telescope
94	**Bond**	http://go-lab.gw.utwente.nl/production/bond/build/bond.html	http://www.golabz.eu/lab/bond
95	**StarORF**	http://star.mit.edu/orf/runapp_html.html	http://www.golabz.eu/lab/staroorf
96	**pH Scale**	https://phet.colorado.edu/sims/html/ph-scale/latest/ph-scale_en.html	http://www.golabz.eu/lab/ph-scale
97	**Molarity**	https://phet.colorado.edu/sims/html/molarity/latest/molarity_en.html	http://www.golabz.eu/lab/molarity
98	**Gravity Force Lab**	https://phet.colorado.edu/sims/html/gravity-force-lab/latest/gravity-force-lab_en.html	http://www.golabz.eu/lab/gravity-force-lab
99	**Area Builder**	https://phet.colorado.edu/sims/html/area-builder/latest/area-builder_en.html	http://www.golabz.eu/lab/area-builder
100	**Free Fall**	http://www.remlabnet.eu/?page=exp&i	http://www.golabz.eu/lab/free-

		d=14&lang=en	fall
101	**Transient in RLC**	http://www.remlabnet.eu/?page=exp&id=18&lang=en	http://www.golabz.eu/lab/transient-rlc-0
102	**Planets**	http://evilfer.github.io/planets	http://www.golabz.eu/lab/planets
103	**Faraday's law**	http://www.remlabnet.eu/?page=exp&id=15&lang=en	http://www.golabz.eu/lab/faraday%E2%80%99s-law
104	**Phase in RLC**	http://www.remlabnet.eu/?page=exp&id=16&lang=en	http://www.golabz.eu/lab/phase-rlc
105	**Transient in RLC**	http://www.remlabnet.eu/?page=exp&id=6&lang=en	http://www.golabz.eu/lab/transient-rlc
106	**Electrochemical cell**	http://www.remlabnet.eu/?page=exp&id=2&lang=en	http://www.golabz.eu/lab/electrochemical-cell
107	**Building Inorganic Molecules**	http://www.3dtrainingdesign.co.uk/GoLab/Molecules/Molecule-IONIC_COVELANT_BONDING/Molecule-IONIC_COVELANT_BONDING-v1.0.html	http://www.golabz.eu/lab/building-inorganic-molecules
108	**Building Atomic Orbitals**	http://www.3dtrainingdesign.co.uk/GoLab/Molecules/Molecule-ORBITALS/Molecule-ORBITALS-v1.2.html	http://www.golabz.eu/lab/building-atomic-orbitals
109	**Orfeus Earthquake Data Center**	http://www.orfeus-eu.org/odc/navigator.html	http://www.golabz.eu/lab/orfeus-earthquake-data-center
110	**Σεισμοί στην Ελλάδα**	http://www.seismoi.gr/arxeio.htm	http://www.golabz.eu/lab/σεισμοί-στην-ελλάδα
111	**Meteo Trnava**	http://www.remlabnet.eu/?page=exp&id=1&lang=en	http://www.golabz.eu/lab/meteo-trnava
112	**Emission of LEDs**	http://www.remlabnet.eu/?page=exp&id=8&lang=en	http://www.golabz.eu/lab/emission-leds
113	**Source of DC**	http://www.remlabnet.eu/?page=exp&id=7&lang=en	http://www.golabz.eu/lab/source-dc
114	**Energy in RLC**	http://www.remlabnet.eu/?page=exp&id=3&lang=en	http://www.golabz.eu/lab/energy-rlc
115	**Free Fall in Vacuum**	http://www.remlabnet.eu/?page=exp&id=4	http://www.golabz.eu/lab/free-fall-vacuum
116	**Archimedes' Law**	http://www.remlabnet.eu/?page=exp&id=9	http://www.golabz.eu/lab/archimedes%E2%80%99-law

117	**Sun Shadow Visualizer**	https://dl.dropboxusercontent.com/u/29419116/Soeren%20Werneburg.html	http://www.golabz.eu/lab/sun-shadow-visualizer
118	**Simple Pendulum**	http://www.remlabnet.eu/?page=exp-inf&id=5	http://www.golabz.eu/lab/simple-pendulum

Annex D – Letter sent to stakeholder to invite them for an interview on the Big Ideas of Science

Dear [**Name**] [**Surname**],

We are contacting you on behalf of the consortium of the Go-Lab project (http://go-lab-project.eu/) which is funded by the European Union's Seventh Framework Programme. The Go-Lab Project aims to create a federation of online labs so as to increase their use by students and teachers into the science school classroom. To further enhance this aim, the project team is also providing a large pool of inquiry-based activities which allow the use of the online labs within a cutting-edge environment designed for students.

The project team is highly interested in promoting an effective organization of the online labs and related activities so as to facilitate the teachers in planning and delivering multidisciplinary activities that demonstrate the interconnection between different science subjects as well as between what is taught in the school class and the world around us.

To this end we would like to invite you to a short interview/discussion about the organization of multidisciplinary science activities within the curriculum of your country and about the current status of collaboration between science teachers in order to help the students understand the aforementioned interconnections.

We are looking forward to hearing from you.

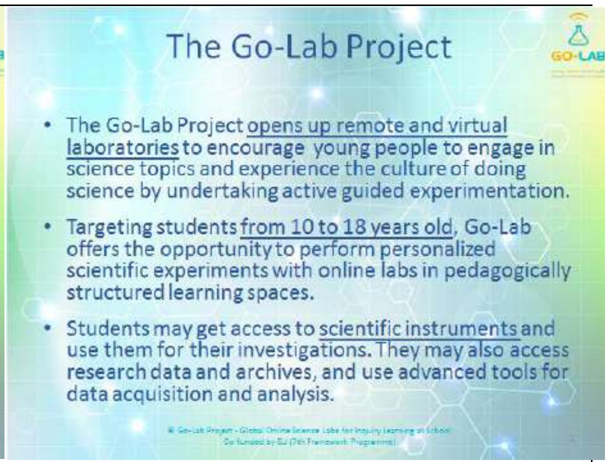
Sincerely yours,

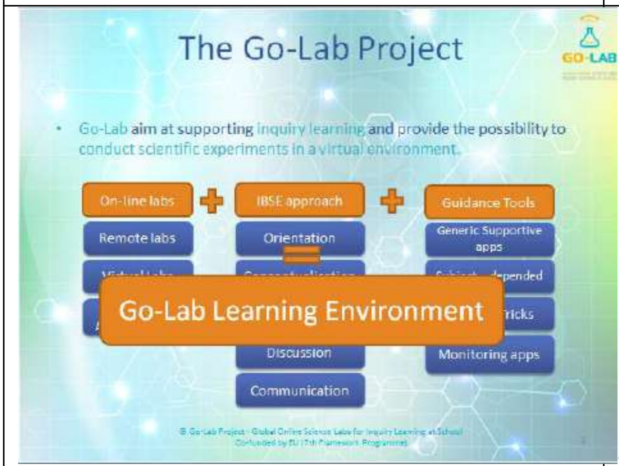
[**Name**] [**Surname**]

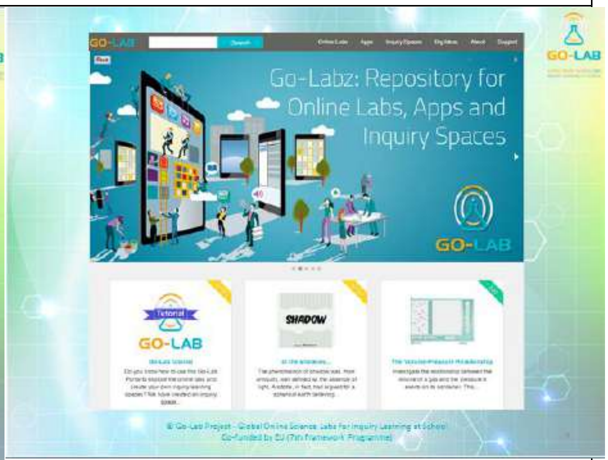
[**Go-Lab Partner**]

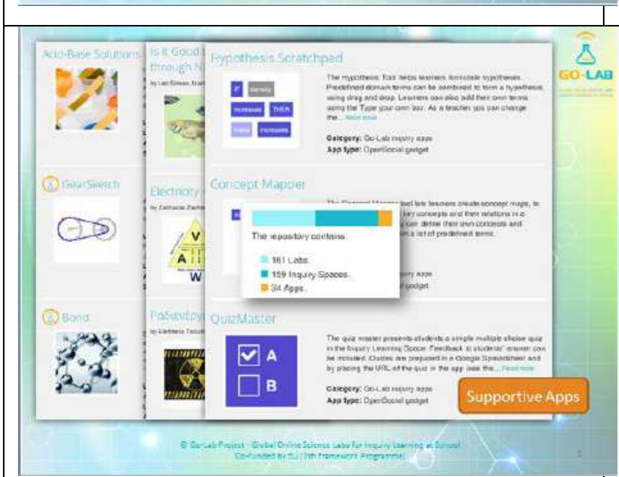
On behalf of the Go-Lab Consortium

Annex E – PowerPoint presentation used during the interviews on the Big Ideas of Science with stakeholders



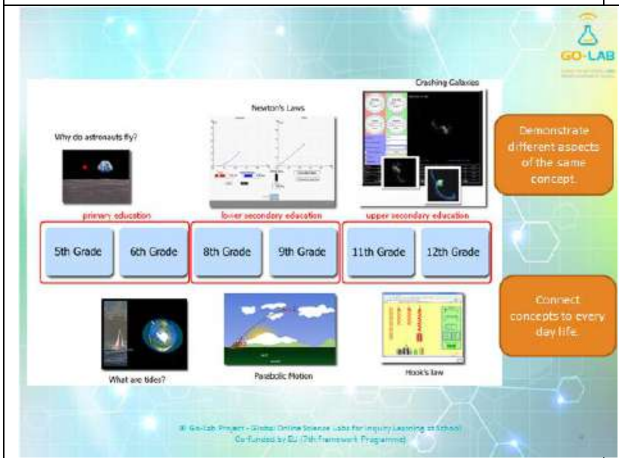


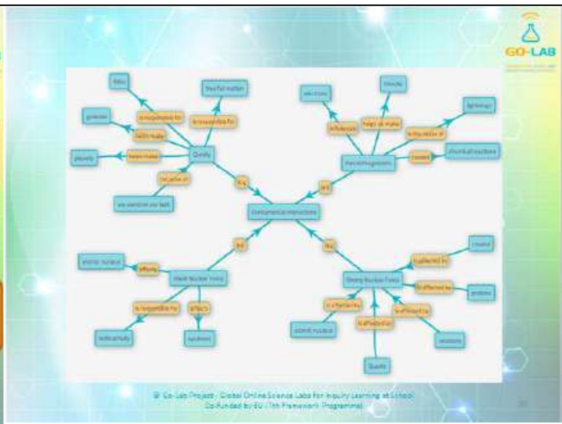





Going multidisciplinary
GO-LAB
• The Challenge:
Introduce an organization scheme that goes beyond the typical ones which helps teachers introduce to their classrooms activities as a progression from small, beginning ideas, followed by the bigger ones which can be developed to encompass a wider range of experiences, leading to the broad, more abstract ideas that enable understanding of objects, phenomena and relationships in the natural world.

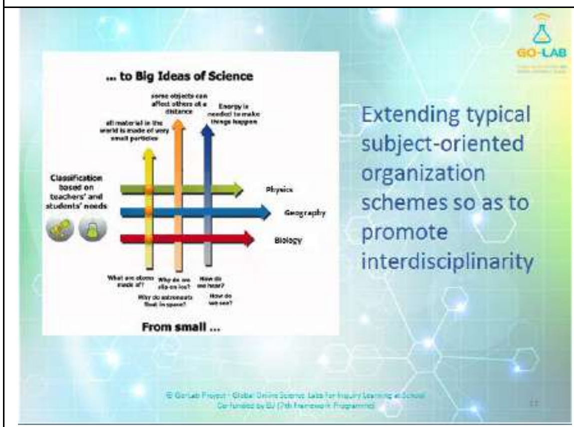

GO-LAB
primary education
lower secondary education
upper secondary education
5th Grade
6th Grade
8th Grade
9th Grade
11th Grade
12th Grade
Make connections to subject taught in previous classes.
Give insights for subject that they students will be taught in next classes.

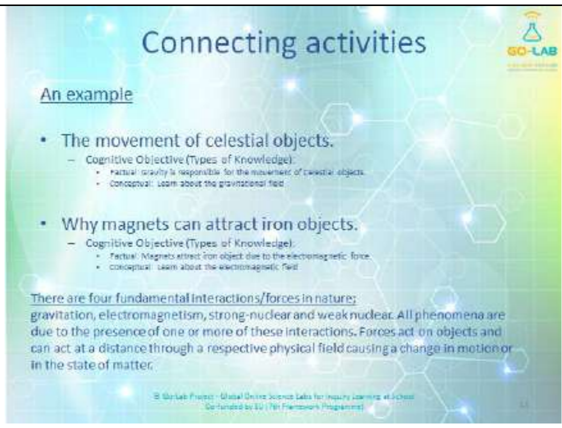

GO-LAB
Why do astronauts fly?
Newton's Laws
Crashing Galaxies
primary education
lower secondary education
upper secondary education
5th Grade
6th Grade
8th Grade
9th Grade
11th Grade
12th Grade
Demonstrate different aspects of the same concept.
Connect concepts to every day life.
What are tides?
Parabolic Motion
Hook's law

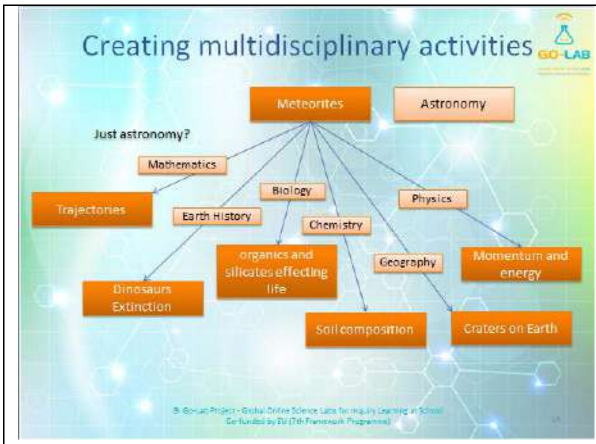

GO-LAB

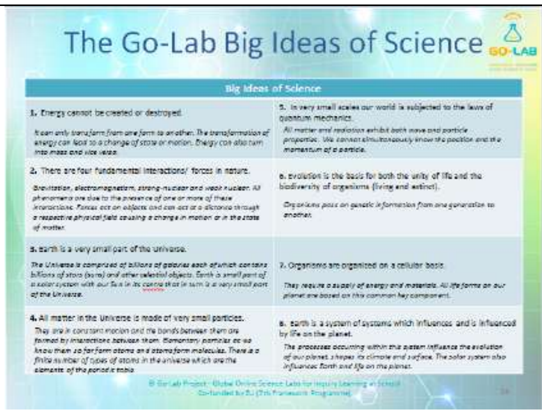

GO-LAB
gravity
energy
radiation
magnets

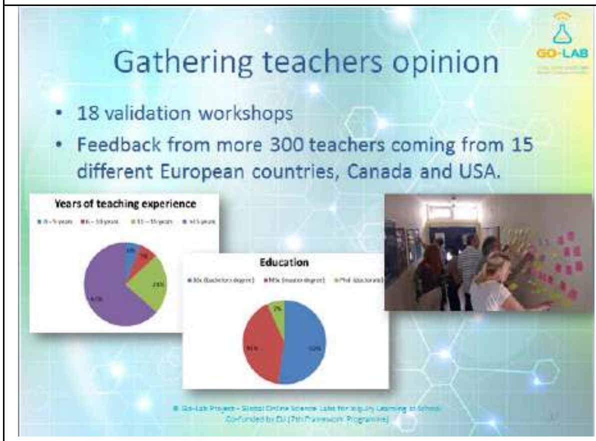

Going beyond
GO-LAB
• Meeting the challenge:
The "Big Ideas of Science"
A set of cross-cutting scientific concepts that describe the world around us and allow us to conceive the connection between different natural phenomena.

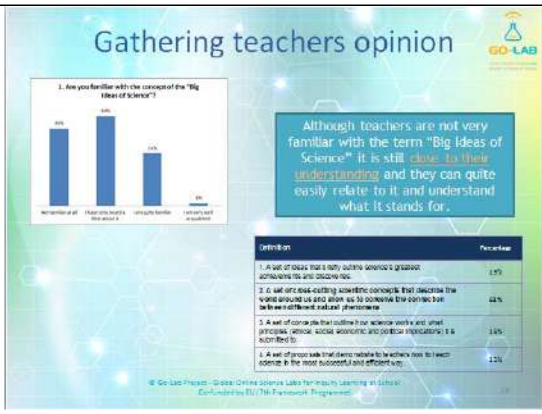

GO-LAB
... to Big Ideas of Science
Classification based on teachers' and students' needs
Physics
Geography
Biology
From small ...
Extending typical subject-oriented organization schemes so as to promote interdisciplinarity

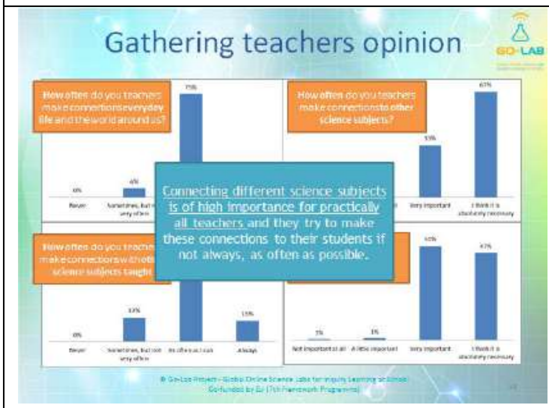

Connecting activities
GO-LAB
An example
• The movement of celestial objects.
– Cognitive Objective (Types of Knowledge):
• Conceptual: Learn about the gravitational field
• Why magnets can attract iron objects.
– Cognitive Objective (Types of Knowledge):
• Factual: Magnets attract iron object due to the electromagnetic force.
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.

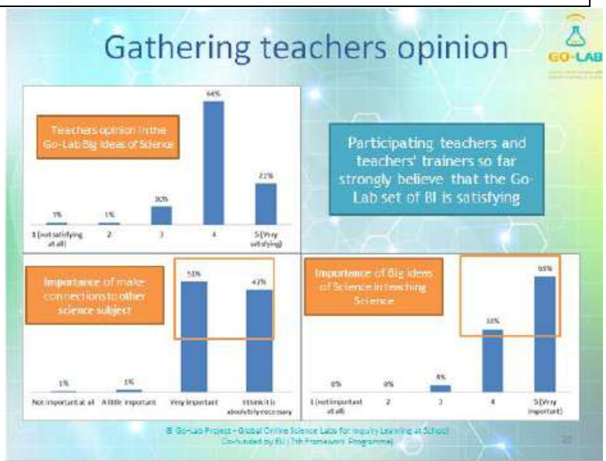

Creating multidisciplinary activities
GO-LAB
Meteorites
Astronomy
Just astronomy?
Mathematics
Biology
Physics
Trajectories
Earth History
Chemistry
organics and silicates effecting life
Geography
Momentum and energy
Dinosaurs Extinction
Soil composition
Craters on Earth


The Go-Lab Big Ideas of Science
GO-LAB
Big Ideas of Science
1. Energy cannot be created or destroyed.
2. There are four fundamental interactions/ forces in nature.
3. earth is a very small part of the universe.
4. All matter in the Universe is made of very small particles.
5. In very small scales our world is subjected to the laws of quantum mechanics.
6. evolution is the basis for both the unity of life and the biodiversity of organisms (living and extinct).
7. Organisms are organized on a cellular basis.
8. earth is a system of systems which influences and is influenced by life on the planet.


Gathering teachers opinion
GO-LAB
• 18 validation workshops
• Feedback from more 300 teachers coming from 15 different European countries, Canada and USA.
Years of teaching experience
Education


Gathering teachers opinion
GO-LAB
Although teachers are not very familiar with the term "Big Ideas of Science" it is still close to their understanding and they can quite easily relate to it and understand what it stands for.
Definition
Percentage


Gathering teachers opinion
GO-LAB
How often do you teachers make connections to other science subjects?
Connecting different science subjects is of high importance for practically all teachers and they try to make these connections to their students if not always, as often as possible.


Gathering teachers opinion
GO-LAB
Teachers opinion in the Go-Lab Big Ideas of Science
Participating teachers and teachers' trainers so far strongly believe that the Go-Lab set of BI is satisfying
Importance of make connections to other science subject
Importance of Big Ideas of Science in teaching Science