Go-Lab

Global On-line Science Labs for Inquiry Learning at School

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Recommendations for the introduction of on-line labs in schools

Editor(s)	Dr. Sofoklis A. Sotiriou (EA)
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Beneficiary Number	Beneficiary name	Beneficiary short name	Country
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2	Ellinogermaniki Agogi Scholi Panagea Savva AE	EA	Greece
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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
Sofoklis Sotiriou, Eletheria Tsourlidaki, Jens Koslowsky, Vassilis Karamounas, Fani Stylianidou, Giorgos Mavromanolakis	EA
Internal Reviewers	
Evita Tassiopoulou	EUN
Danilo Garbi Zutin	CUAS

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Executive Summary

This document contains the outcome of the work done during the 4th year of the project in task "T9.6 – Recommendations for the introduction of on-line labs in schools". Its aim is to act as a set of guidelines that summarizes the experience gained during the project on how to effectively introduce remote and virtual labs (on-line labs) in science classrooms in Europe. The content is mainly based on the approaches adopted in; a) the organization of the on-line labs of the Go-Lab Repository, b) the tools that were offered to the teachers to create their own educational activities by developing, adopting or using existing Inquiry Learning Spaces (term used to describe the lab-based assignments to students in the framework of school-based or project based work) , c) the support mechanism that was developed and implemented to facilitate teachers work and d) the findings which resulted in the framework of the extended implementation work of the project which is parallel with the evaluation results. The aim is a) to make available to all European science teachers a common framework for the design, development, organization and sharing of resources, methods and tools that promote the use of remote and virtual labs in school and b) to make available on-line labs providers and curriculum developers; a set of guidelines and recommendations for the design of resources to be used in schools.

Following the development of a series of inquiry based activities that demonstrates the potential use of on-line labs in the classroom environment and an extended implementation phase with the involvement of numerous teachers and students across Europe, the aim of the consortium is to constitute a common set of guidelines and recommendations on how scientific work can be used to provide an engaging educational experience through the exploration of "real science". Research on learning science makes it clear that it involves development of a broad array of interests, attitudes, knowledge, and competencies. Clearly, learning "just the facts" or learning how to design simple experiments is not sufficient.

In order to capture the multifaceted nature of science learning, the Go-Lab approach proposes a roadmap that includes a series of recommendations that articulates the science-specific capabilities supported by an innovative web-based environment that promotes the scientific culture. These recommendations provide a framework for thinking about elements of scientific knowledge and practice. The proposed framework also describes a series of support functions that have to be deployed in order for the long-term impact of the proposed activities to be safeguarded.

The proposed framework provides a useful reference not only for curriculum developers but also for helping outreach groups to articulate learning outcomes as they develop programs, activities, and events to further explore and exploit the unique benefits of introducing on-line labs in schools. Furthermore, such an action asks for knowledge areas integration, effective and closes cross-institutional collaboration, and organisational change in the field of science education.

This document presents the main areas of action of the Go-Lab large scale pilot initiative and discusses the approach used to introduce on-line labs related activities in everyday school practice. It emphasizes on the collaboration with the teachers and concludes with a list of recommendations for the outreach teams of research infrastructures for the design of their activities targeting schools.

The data presented in this deliverable are based on different surveys and deliverables of the project. This deliverable is focusing on presenting an integrated approach and a series of recommendations for different stakeholders. More specifically the data are coming from Deliverables D2.1, D2.2 D2.3 and D2.4, "The Go-Lab Inventory and Integration of online labs", D6.5 and D6.7 "Report on development of the virtual Go-Lab User Community", D7.6 "Report on the implementation Activities", D8.3 and D8.4 "Validation and Evaluation Report and Recommendations".

Audience

This is a public document. The target audience are curriculum developers and educational policy makers who want to make the existing science curricula more engaging and interesting through the integration of on-line experimentation and on-line labs providers who want to expand the use of their labs to numerous European schools.

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1. Introduction

1.1 Scope

The Go-Lab project has as its goals to encourage young students to: a) engage in science topics, b) acquire scientific inquiry skills, and c) experience the culture of doing science, under motivating circumstances, by undertaking active, guided, experimentation, carried out on more basic and top-level scientific facilities.

To achieve this, the Go-Lab inventory offers a federation of remote laboratories, virtual experiments, and data-sets (together referred to as "**on-line labs**") facilities to embed these on-line labs in pedagogically structured **learning spaces** by teachers and that also offer students **cognitive scaffolds** and **opportunities for social interaction**. The aim of Go-Lab was to leverage on existing on-line lab repositories and increase their accessibility by offering lightweight end-user interfaces. Go-Lab's on-line labs are fit to be integrated into regular classroom activities. To facilitate this process, Go-Lab offers pedagogical and technical **plug (ease of integration)**, **play (ease of use),** and **share (ease of consolidation)** methodologies and infrastructures to teachers: a) to guide the preparation of inquiry activities by the facility which compose of dedicated learning spaces, b) to access resources that facilitate the design of realistic and engaging activities, c) to adopt, enrich, and/or modify these activities through an on-line community.

Go-Lab's resources come from large scientific organizations, from universities and research institutions, as well as from dedicated companies. Go-Lab offers these lab-owners: a) open interfacing solutions to easily plug their real experiments on-line and construct their virtual didactic counterparts, b) increased visibility and attraction, and c) unique opportunities for stimulating dialogue between (young) scientists and students. The Go-Lab consortium has managed to demonstrate effective ways for involving a broader set of actors in the use of on-line labs (including advanced experimental facilities like CERN detectors, robotic telescopes and microscopes as well as by providing access to unique scientific data): a) by developing a framework of actions that will **attract young people to science and pool talent to scientific** careers and b) **to foster a culture of cooperation between research infrastructures outreach groups, on-line labs providers and schools**, by spreading good practices between outreach groups of large scale research infrastructures, research institutions and universities, thus, encouraging them to develop their activities in complementary ways and c) **to   optimize the educational use of on-line labs by demonstrating how they could support the vision of the science classroom of tomorrow.**

These three main impacts of the Go-Lab initiative were achievable by realizing the three main enabling (pedagogical) aims of the project, namely the development of a) a federation of on-line labs organized in such a way to facilitate pedagogical plug and play in science classrooms, b) *a pedagogical framework for inquiry learning with on-line labs that sets the framework for the development of numerous demonstrators (scenarios of use) and c)* a community of practice that implemented the project activities at large scale in Europe and that will form the main vehicle of the project's sustainability.
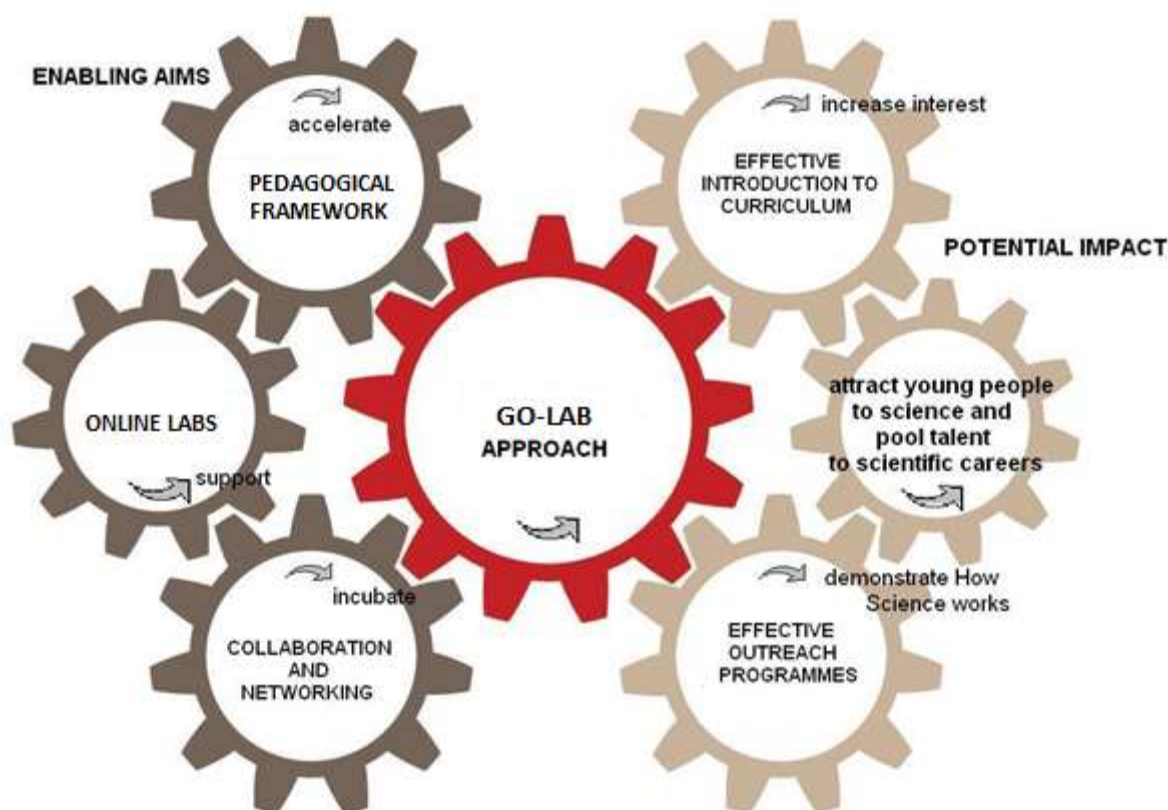
Figure 1. The Go-Lab large scale initiative aimed to set into operation a mechanism that demonstrates how on-line labs could provide powerful tools for scaling-up current pilot implementations for effective introduction of inquiry learning in the school curriculum and development of effective outreach programmes through the provision of high quality scientific content and data to schools. The graphical representation above demonstrates how the Go-Lab mechanism supports (through on-line labs), incubates (through effective collaboration and community development) and finally accelerates (through the Go-Lab pedagogical plug and play) the introduction of innovation in science classrooms in order to demonstrate how science works and to increase the interest of the students in science.

1.2   Attract young people to science and pool talent to scientific careers

The Go-Lab mechanism (see Figure 1) was supported by the following coordinated actions:

By simulating in the classroom the work of the researcher

The direct interaction with science or the doing of science reflects a fundamental pedagogy of the Go-Lab project which provides students with personal and direct experiences that they can build upon in their own ways. For example, through the use of the rich repository of on-line labs, students experience the phenomena presented in their own terms, freely choosing what to attend to and interact with, depending on their prior knowledge, interest and expertise. The on-line labs are integrated in the classroom environment and they are used in meaningful activities related with science curricula. The use of the Inquiry Learning Spaces (a simulation of the lab bench enriched with numerous support tools for experimentation and analysis) facilitates this process. Inquiry Learning Spaces do not act simply as "demonstrations" of scientific research, but primarily as interactive and vivid

initiatives where students equipped with powerful applications, scaffolds and analysis tools become the researchers, the seekers and finally the leaders of the scientific quest. To this end, the Go-Lab Inventory offers innovative, interactive, collaborative and context-aware tools and functionalities, which are student-centered, focusing on contextualized and adaptable learning experiences. In addition, students have the opportunity through the Go-Lab Inventory and the proposed tools to interact with researchers in live internet chats and webcasts (e.g. the Virtual CERN visit events were initiated in the framework of the Go-Lab initiative), asking questions and hearing them describe their work (and their lives).

Figure 2. The ATLAS Virtual Visits web site that was developed to support the numerous e-Master classes events organized in the framework of the Go-Lab project. Numerous schools from all over Europe were involved in these activities.

In physical and virtual visits to the research infrastructures and in videos, students hear about the work of a researcher and watch them in the field using the scientific infrastructures themselves. Having role models, developing relationships with mentors and gaining job experience are all mentioned in the literature as factors which enables young people to picture themselves succeeding in a science or a technology career (Hill et al., 1990[i]; Packard and Nguyen, 2003[ii]; Madill et al. 2004[iii]).

By promoting a better understanding of 'how science works'

The activities that were organized in the framework of the Go-Lab extended pilots introduced students to concepts and ideas of science of a multidisciplinary nature spanning all science disciplines, mathematics and engineering. As such, they safeguard sustained intellectual engagement by majority of students, while promoting the interest of the few who will choose to pursue careers in science. In the framework of the educational activities implemented, the students were asked to employ real-problem solving skills, to handle and study situations, and to engage in meaningful and motivating science inquiry activities. Adopting this approach, the dynamic character of scientific thought was efficiently assimilated, stimulating and encouraging the creative minds of the participating students. By engaging in scientific activities, students can also develop greater facility with the language of scientists; terms like hypothesis, experiment, and control begin to appear naturally in their discussion of what they are learning. In these ways, students begin to gain entry into the culture of the scientific community and start to change the way they think about themselves and their relationship to science. They think about themselves as science students and develop an identity as someone who knows about, uses, and sometimes

contributes to science. In this way, the Go-Lab initiative did not just add its contribution to the preparation of some students as expert, but also for all students to generate original and creative work that is required by a knowledge-based economy. Additionally, by extending the dialogue and direct contact between schools research organizations, universities and other on-line lab providers, the project promoted scientific and innovative culture in young people and helped them acquire a better understanding of the role of science and technology in society. The project approach has contributed to the opening of the science classroom in the field of research offering first hand opportunities for direct interaction between the students and the world of science, technology and industry.

Today, much of the ethical and political decision-making involves some understanding of the nature of science, its strengths and limits. There is perhaps no better or more recent example of this need, than the debate that arose during the operation of LHC at CERN, which ignited the imagination of authors of works of fiction, occasionally causing concern among the general public. To understand the role of science in deliberations about the projected outcomes of the experiments taking place in the LHC, their safety and value - given the immense investment in human and other resources involved- all students, including future scientists need to be educated to be critical consumers of scientific knowledge. The Go-Lab project activities improved both students and teachers' ability to engage with such debates, since they not only impart a knowledge of the content, but also a knowledge of 'how science works', "an element which should be an essential component of any school science curriculum" (Osborne and Dillon, 2008)[iv]. They also immensely encourage critical and creative ways of thinking and enhance young people's critical attitudes to science and its experiments. When students get involved in the project's activities they appreciate the challenges and limitations of an experiment or observation and as a result develop a better understanding of the nature of scientific knowledge.
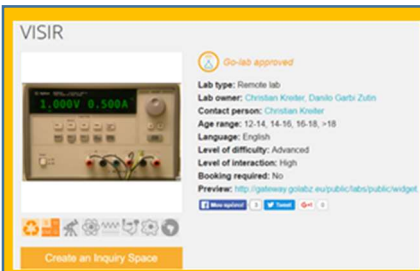
By enhancing students' science related career aspirations

The Go-Lab approach has managed to address another recommendation of the Osborne and Dillon (2008)[4] report that efforts should be expended to ensure that students' early encounters with science before the age of 14 be as stimulating and engaging as possible, since their interest in science is largely formed by this age. Occupational preferences developed during the formative years which in turn, have also shown to shape the course of future career development and adult occupational attainment (Bandura et al., 2001[v]; Schoon, 2001[vi]; Schoon and Parsons, 2002[vii]). More particularly in science, relevant aspirations expressed at age 16 have proved to be strong predictor for entering a scientific career (Schoon et al., 2007[viii]). In this framework, the Go-Lab Inquiry Learning Spaces included interactive career counseling approaches in order to increase awareness of the value of studying science among students by demonstrating potential career opportunities. More precisely, the educational activities offered young students opportunities for extended investigative work and 'hands-on' experimentation through outreach activities such as the remote control of a robotic telescope that is located to the other side of the planet, by simplifying the context of use for already existing on-line applications and by creating new ones explicitly linked to the school science curriculum. The Go-Lab team has explicitly developed such science related occupational aspirations, by demystifying the work of the researcher, making it familiar and tangible for younger students, who through the use of the tools and processes used by 'real' researchers got a first-hand experience both of what skills are needed in the job and of how it feels like 'doing the job'. On the other hand, the

use of such innovative applications in school helped to authenticate curriculum work, as students can see first-hand the relevance and application of the science learnt in the classroom, in the real world. This is important and breaks the obstacles of current school curriculum practice, in which school science is often presented as a set of stepping-stones across the scientific landscape and lacks sufficient exemplars that illustrate the application of science to the contemporary world that surrounds the young person, who thus perceives it as irrelevant to his/her life and loses interest in it.

By promoting inquiry-based science teaching and learning

The Go-Lab approach brings the use of on-line labs and relative innovative applications to school students in a meaningful way. These tools promote science teaching and learning as a process of inquiry as well as technological thinking as a process of problem solving. They act as the window onto live scientific experiments and phenomena, ongoing scientific research, and the personalities and stories of working scientists across the globe. For example, the project has provided numerous students and teachers with the opportunity to access and use remotely robotic telescopes in real time, interact with scientists from ESA and other research institutions, perform experiments using experimental devices from university laboratories across Europe, simulate quite complex phenomena, interact with the microcosms, collect data from seismometers across the world, perform observations, analyze data and results from CERN detectors and finally develop and suggest solutions and provide answers to selected research – scientific topics.

The VISIR system provides an environment in which students can construct and test different circuits with a degree of freedom normally associated with a traditional, hands-on electronics laboratory. The great advantage of VISIR system was that the on-line workbench offered included equipment that was identical with the laboratory equipment and the topics that could be taught with the use of this tool were also very similar or even identical to the topics that had already been taught in terms of the actual laboratory lesson.

In doing so the project's approach promotes a reversal of school science teaching pedagogy from mainly deductive to inquiry-based methods, which is more likely to increase students' interest and attainment in science, according to two recent and important publications in science education 'Science Education in Europe: Critical Reflections' (Osborne and Dillon, 2008)[4] and 'Science Education Now: A renewed Pedagogy for the Future of Europe' (Rocard et al., 2007)[ix].

By tackling the gender gap in science

A further concern shared by both the world of school science education and the world of scientists and researchers is the under-representation of females in the uptake of science studies and careers, despite concerted efforts to address this in the last 30 years. Whilst there is still some debate about whether females' proportionally lower engagement with the study of science is innate or cultural, there is a high level of concern that both females and science are losing out: girls by foreclosing a number of career options, and science by failing

to attract students with potentially significant contribution to make (Osborne and Dillon, 2008)[4]. The Go-Lab initiative has helped counteract this imbalance by:

- using in the pedagogical materials produced a variety of social situations and contexts to illustrate scientific problem solving – using topics to show how science impacts on people;
- promoting inquiry based pedagogical strategies proven to be popular amongst females, e.g. the use of argumentation
- representing science as something people do and not just a body of knowledge;
- using the contexts of space exploration and life discovery for the application of the selected on-line labs, contexts that have proved to be interesting to boys and girls alike;
- including in the Go-Lab interface support systems to encourage students who lack confidence in taking the plunge to try something different;
- including in the Go-Lab portal popular communication and social networking tools, proven to be popular with females;
- ensuring that all dissemination materials have positive images and are not exclusively male dominated and unimaginative;
- integrating awareness of gender bias in the teacher training activities – challenging often unconscious barriers in attitude and language;
- including advice on tackling gender issues in the roadmap for development of outreach and awareness activities.
- empowering science teachers to effect change.

None of the above actions can be accomplished without the full collaboration and engagement of teachers and their schools. The project has offered opportunities for teachers' professional development, including occasions to interact with working scientists, science contests, workshops, international summer schools and training seminars to help them to introduce on-line labs in their science classroom, and more generally think differently about their students' learning of and about science. By offering teachers a large repertoire of tools and applications, along with a detailed school-based framework for their effective introduction in the school practice (the Go-Lab Inquiry Learning Spaces), the Go-Lab approach empowers teachers not only to change their teaching practice and introduce contemporary scientific issues in their lessons, but also to propose and initiate the necessary changes in their schools, to allow for a more seamless introduction of ICT-based innovations.
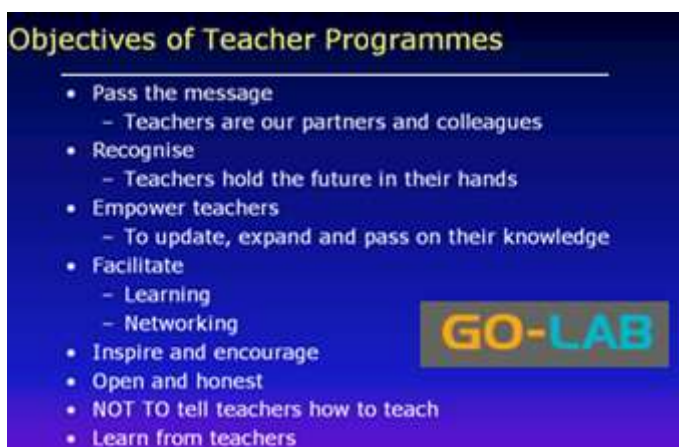
Figure 3. The main teacher-centered objectives of the Go-Lab Teacher Programmes. Recognition of their role, encouragement to their work and respect for their professionalism are the key parameters of the success of this great outreach programme.

Moreover, the teachers who participated in the project became curriculum developers themselves (more than 1000 Inquiry Learning Spaces were developed by teachers who participated to the Go-Lab workshops and training activities), validating thus the proposed approach and methods. According to the National Science Education Standards (NRC, 1996[x]) "the challenge of professional development for teachers of science is to create optimal collaborative learning situations in which the best sources of expertise are linked with the experiences and current needs of the teachers". The Go-Lab approach addresses this challenge by its mere composition and furthermore contributed in tackling it explicitly in its project outcomes.

1.3 To foster a culture of cooperation between research infrastructures outreach groups, on-line labs providers and schools

The Go-Lab approach (see Figure 1) was accelerated by the following coordinated actions:

By demonstrating an effective co-operation scheme between outreach groups and schools

By spreading the use of existing effective outreach mechanisms and educational good practices between major research infrastructures, universities and on-line labs providers (including commercial partners) the Go-Lab project in its mere inception provides a model of effective co-operation between on-line labs providers and school communities. The Go-Lab initiative has created a pool of 400 on-line labs which cover the entire STEM spectrum. In addition, the on-line labs of the Go-Lab inventory targets a wider range of ages than the originally anticipated range covering students from 6 to 18 years old. This is a unique achievement thanks to the effective cooperation of different actors, research infrastructures, universities and on-line lab providers. The Go-Lab consortium has brought together key players in different fields like Particle Physics, Astronomy, Space, Electrical Engineering, that have invested major efforts to introduce frontier research issues into the school's classrooms in Europe and beyond. The project has created virtual learning communities of educators, students and researchers and has involved them in extended episodes of playful learning in the framework of the implementation of the Inquiry Learning Spaces in more than 1000 schools in Europe. Being part of a professional network encouraged interaction and provided them with opportunities to enrich their practices and professional context through cooperation within and between schools, universities, and frontier research institutions, collaborative reflection, development and evaluation of instruction, exchange of ideas, materials and experiences, quality development, cooperation between teachers, students and researchers and support and stimulation from research. The development of such a community consists of a major parameter of success of the coordination action. For example the teams working in the area of High Energy Physics Outreach programmes gain significant experience in communicating scientific ideas by sharing ideas and practices with the Galileo Teacher Training Programme team that is very efficient in developing self-sustained teachers communities across the world.

Fostering a network
We will try to cascade the Go-Lab ideas in Greece following a model similar to the Galileo Teachers Training Program (GTTP) but on a smaller scale i.e. train a few lead teachers; give them certificates and encourage these teachers to become ambassadors by training others within their school or school partnerships. This will be kick-started by our Teaching Fellows, who having used already Go-Lab materials in the classroom, will be effectively our first ambassadors.

IASA Team Report, August 2016

Working in an open fashion is something that researchers themselves can be encouraged to learn, taking into account that in many cases the research groups are coming from competing experiments (e.g. the research efforts of ATLAS and CMS experiments focused on similar research areas for the discovery of Higgs). Learning how to work together, in areas where there is no competition but common targets, has helped the Go- on-line lab providers to become more effective members of the emergent educational community. Sharing certain types of research data is not always possible, but research collaboration need not necessarily be understood only in terms of sharing data.

In fact clarifying the distinction between sharing research data and sharing research infrastructure is a good way of assessing the levels to which various research communities are prepared to collaborate. By encountering common problems in the early stages of using shared resources, disparate research teams have the opportunity to talk to each other. This can pave the way to previously inconceivable forms of research collaboration.

By developing a common framework for effective outreach activities

The Go-Lab partners have worked together to develop a common framework for the design and development of a series of Inquiry Learning Spaces that demonstrate the effective introduction of a variety of on-line labs in schools. The current document describes a series of recommendations and support functions that the on-line labs providers have to deploy for the long-term impact of the proposed activities to be safeguarded. Such support actions could include support for: a) the integration and coordination of educational and outreach activities between groups across different research institutions b) the science community and scientists interested in educational and outreach activities c) the education communities interested in scientific content and applications d) special events and activities that provide means and tools for web-based communication and collaboration. The proposed framework provides a useful reference for helping educators and outreach groups in the science education community articulate learning outcomes as they develop programs, activities, and events, and further explore and exploit the unique benefits of introducing on-line labs in schools.

1.4   To optimize the educational use of on-line labs in schools

In an era of increased public accountability, the use of existing research infrastructures by a broader set of actors, expands their benefits to the wider public, including policy makers, and thus optimizes their use and justifies the public nature of their investment. Emerging technology-enhanced learning applications (e.g. media- and process-rich virtual classrooms and immersive collaborative learning spaces, in which students and teachers participate in, and co-construct virtual worlds, use advanced visualizations and 3D

interactive models, or interact with simulations and virtual experiments) require a powerful technological infrastructure able to support such advanced learning and teaching approaches, as well as seeks new ways of increasing their computational resources by means of individual ones of their integrands. At the same time, although the participation of all educational institutions and learning actors in this new culture is wished and encouraged, a large proportion of Europe's educational communities still have far less than the required computational resources at their disposal.

E-learning systems using client-server, peer-to-peer or web services-based architectures have been developed. Some of the limitations of such systems are scalability, distribution of computing power and storage capabilities. It is also well known that collaborative learning enhancement and efficiency can be achieved through intelligent knowledge management, adaptation, personalization and support provided to all parties involved in the learning process. In this framework the Go-Lab project has managed to demonstrate a) the effective use of resources for the teachers need to scale-up to full classrooms for creating science sessions which incorporate access to a rich collection of on-line labs, research infrastructures, scientist collaborations and ICT support infrastructures and b) the benefits from introducing inquiry learning and experimentation in every European school. The project work offers a series of recommendations for the provision of on-line labs and tools better tailored to the needs of the educational communities, supporting innovation and efficiency in the scientific discovery process. We hope that these findings and the recommendations will increase the potential for on-line labs usage by the school communities.

2. Developing an engaging science classroom

Science programs that reinforce the cooperation of leading researchers provide a solid framework to bringing new instruments and opportunities into modern education thereby providing learners with better opportunities to build their knowledge for the future. Science programs provide an appropriate framework to reinforce a participatory learning approach and to develop instruments for the authentic assessment in science education at all levels.

Education Impact Insight[xi]

The publication of the "Science Education Now: A renewed Pedagogy for the Future of Europe" report (Rocard, 2007)[xii] brought science and mathematics education to the top of educational goals of the member states (following similar actions in US in 1996 NRC, 1996[xiii], EDC Center for Science Education, 2007[xiv]). The authors argue that school science teaching needs to become more engaging, based on inquiry based and problem solving methods and designed to meet the interest of young people. **According to the report, the origins of the alarming decline in young people's interest for key science studies and mathematics can be found, among other causes, in the old fashioned way science is taught at schools.** The crucial role that positive contacts with science at a younger age have in the subsequent formation of attitudes toward science has been emphasized in many studies (e.g. PISA, 2014)[xv]. However, traditional formal science education too often fails to foster these, thus affecting negatively the development of adolescents' attitudes towards learning science. Also, as Kinchin (2004)[xvi] has pointed out, the tension created between objectivism (the objective teacher-centered pedagogy) and constructivism (the constructive and student-centered pedagogy) represents a crucial classroom issue influencing teaching and learning. The TIMSS (Third International Mathematics and Science Study) 2003 International Science Report (Martin *et al.*, 2004)[xvii] specifically documented that the three activities accounting for 57 percent of class time were: teacher lecture (24%), teacher-guided student practice (19%), and students working on problems on their own (14%) in science classes in the European countries participating in the study. Furthermore, the recent TALIS (Teaching and Learning International Study) results (TALIS, 2014)[xviii] demonstrate that the current science classroom learning environment is dominated by traditional pedagogies that are not able to support the introduction of the scientific methodology (Figure 4).

Teaching practices
Percentage of lower secondary education teachers who report using the following teaching practices[1]
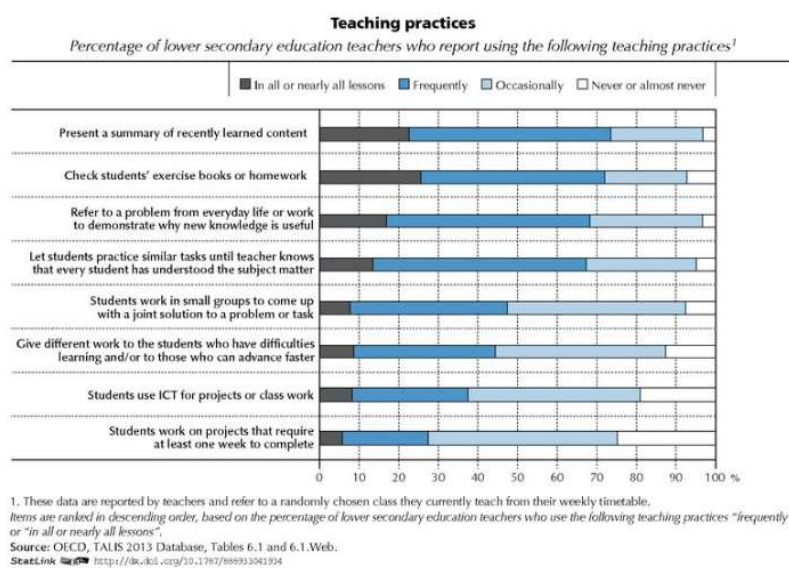
Figure 4. Although significant investments (both at National and EU level) have been made to support the introduction of innovative approaches in science education the classroom practices remaining the same. The recent TALIS results demonstrate that innovative approaches based on inquiry and problem solving methods are used in a small number of classrooms.

The fact is that there is a major mismatch between opportunity and action in most educational systems today. This revolves around the meaning of "science education," a term that is often misappropriated in the current school practice, where **rather than learning how to think scientifically, students are generally being told about science and asked to remember facts** (Alberts, 2009)[xix]. This disturbing situation must be corrected if science education is to have any hope of taking its proper place as an essential part in the education of students everywhere. However, school practices have not changed in ways that reflect this progress. Moreover, modern technologies (e.g. use of social networking tools, remote and virtual labs, advanced visualizations, simulations, virtual worlds and shared collaborative environments), which go beyond the use of simple applications and the internet have not been fully integrated/incorporated in the current science learning environment. According to the recent work performed in the framework of the large scale initiative PATHWAY (Sotiriou & Bogner, 2011)[xx] the deeper problem in science education is one of fundamental purpose. Schools, the authors argue, have never provided a satisfactory education in sciences for the majority. Now the evidence is that it is failing even in its original purpose, to provide a route into science for future scientists. **The challenge therefore, is to re-imagine science education: to consider how it can be made fit for the modern world and how it can meet the needs of all students; those who will go on to work in scientific and technical subjects, and those who will not**.

In our view, **the science classroom** should provide more challenging, authentic and higher-order learning experiences, more opportunities for students to participate in scientific practices and tasks, using the discourse of science and working with scientific representations and tools. It should enrich and transform the students' concepts and initial ideas, which could work either as resources or barriers to emerging ideas. The science classroom should offer opportunities for teaching tailored to the students' particular needs while it should provide continuous measures of competence, integral to the learning process that can help teachers work more effectively with individuals and leave a record of competence that is compelling to students.

There are already numerous Inquiry Learning Spaces on the Go-Lab portal that are promoting the use of on-line labs in school classrooms. They demonstrate how

students can access remote research databases, use scientific instruments and data analysis tools, and advanced infrastructures in innovative ways. This field has huge potential for engaging students in scientific inquiry and debate and thus to contribute to the teaching of the skills necessary to participate in or follow public debates on scientific issues.

3. Trust to teachers' professionalism

3.1 Go-Lab Teachers Profile

The Go-Lab large pilot experimentation involved more than 1500 science teachers from more than 1000 European schools. Although the sample cannot be characterized as representative in the participating countries it offers some good insights that curriculum developers and on-line labs providers must keep in mind when proposing the introduction of on-line experimentation in the school curricula. It is very important to have a clear overview of the experiences and the skills of science teachers as well as a good knowledge of the environments where teachers operate. A close look at teachers teaching and technical skills reveals that a large percentage of the teachers that are interested in the use of on-line labs have quite developed pedagogical and technological skills. Thanks to the diversity of options that the Go-Lab tools offer, teachers with less experience have the possibility to start discovering the tools by using the repository and identifying labs, apps and existing ILSs that fit their needs. This is a crucial parameter for such interventions.

One has to design both innovations and tools having in mind the variety of needs and the different circumstances in the school settings across Europe. The findings of our experimentations are presented to summarize the characteristics of the teacher sample involved in the project.

In the framework of the Go-Lab project the pedagogical model used was based on inquiry approach. One can consider that the focus of inquiry results in more complex and demanding interventions but according to our view the integration of on-line labs in school curricula has to be based on a strong pedagogical framework. In any case IBSE is currently in the agenda of the most educational reform efforts in Europe. Most of the Go-Lab teachers have some knowledge of IBSE. The majority of teachers seem confident in teaching IBSE to their students and to design related activities. Still a significant number of teachers do not feel confident using IBSE. Some consider that they still lack skills in order to successfully apply it. For others, the problem remains to be the curricula restrictions that do not offer space for such interventions. Continuous support, good practices and training are needed in order support teachers interested in IBSE and help them fully develop their IBSE skills. It has to be noted that the focus on IBSE was a design decision of the Go-Lab taking into account that numerous reform efforts in European countries bringing IBSE as a top priority of their agendas.

Could on-line labs lower the barrier that is the time constrains in the implementation of IBSE interventions in classrooms? According to our view, Go-Lab has managed to optimize the use of on-line labs as a way to introduce IBSE in school classrooms. Teachers seem to be quite confident to use on-line laboratories and repositories. The use of authoring tools though, is a big challenge for most teachers which also affects their intentions and ways they use the Go-Lab tools. At the end of the second phase of pilot work we can see a change in teachers' technical skills with a significant rise in the numbers of teachers who are developing their own educational materials. The various supportive materials that were made available in the course of the previous year and the training sessions that took place all around Europe, have definitely played their role and contributed to this change.

It is important to note that both curriculum developers and on-line labs providers should make sure that effective and continuous technical support has to be provided to the teachers. More specifically on-line lab providers should follow modular and flexible support schemes to cover the different teachers training needs.

Teachers as co-designers of the reform efforts: The use of Go-Lab helped teachers to gain familiarity with the basic principles of authoring tools that they can use in producing their own ILS. As a result, we can see a great shift regarding the use of Go-Lab. This is a very important outcome according to our view. Both curriculum developers and on-line labs providers could rely on teachers for the development of educational materials that will facilitate the integration of on-line labs to the curriculum. Teachers have the knowledge and the skills to adopt and design localized scenarios adapted to their classroom needs. The user-friendliness and the usability of the tools are crucial here.

On-line labs providers should make sure that their services are accompanied with the necessary support infrastructure that will give teachers the opportunity to localize the proposed tools to their lessons. This approach holds a great potential. Teachers can become participants in the reform processes by designing innovative scenarios but at the same time introducing new scientific knowledge that is not available to the current curricula.

Need for reward mechanisms: Additional actions need to be taken it order to motivate teachers to fully participate in the validation process. Incentives, rewards, connection to certification are just some of the suggestions and possible solutions that have to be considered. If teachers are becoming co-designers of the reform efforts specific recognition mechanisms have to be in place.

Curriculum developers and on-line labs providers have to trust teachers' professionalism and to devote significant resources on teachers' professional development programmes. The main recommendation from our work is that teachers could be co-designers in the reform efforts. Instead of allocating resources to developing new educational materials curriculum developers have to offer to teachers the appropriate guidance and support to harmonize existing resources to their needs.

In the next section we are presenting the main findings from the Go-Lab experimentation that demonstrates that – under the specific framework – teachers can be effectively introduced in such interventions.

3.2   Behavioural Change: Towards a community of content creators

In the framework of the project implementation we had the chance to monitor a significant change to the attitude of the participating teachers towards the use of on-line labs in their classrooms. Teachers were initially involved in the project, they have tested the offered services and functionalities and finally they have started creating their own inquiry learning spaces. In Figure 5 we can see teachers' replies regarding how they intend to use Go-Lab (survey realized during the first pilot phase of the project, academic year 2014-2015). As we can see, the majority or teachers (48%) entered Go-Lab with the intention to discover

and use on-line laboratories (this was also the message of the project's dissemination strategy). A smaller percentage (28%) was already willing to use complete ILSs that they could adapt and use with their classes while the smallest percentage (24%) was committed to implementing their own ILSs. The pattern is compared to the 1% rule in Internet, which states that 90% of the participants of a community only view content, 9% of the participants edit content, and 1% of the participants actively create new content[1]. In the Go-Lab case, though, the teachers participating appear to be more active than usual.
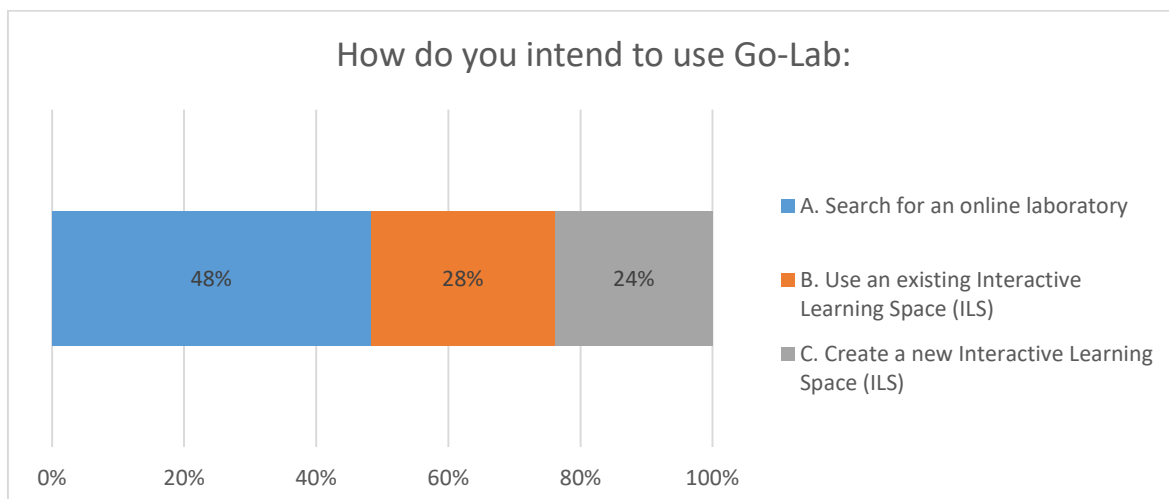
Figure 5. How do teachers intend to use Go-Lab (2014 Survey, D8.3).

Figure 6 shows the data from the survey tool place in late 2015. 51% of the teachers have created their own ILS while 25% of the teachers have used an existing ILS. A small percentage of 25 have used Go-Lab portal only for finding an on-line laboratory.
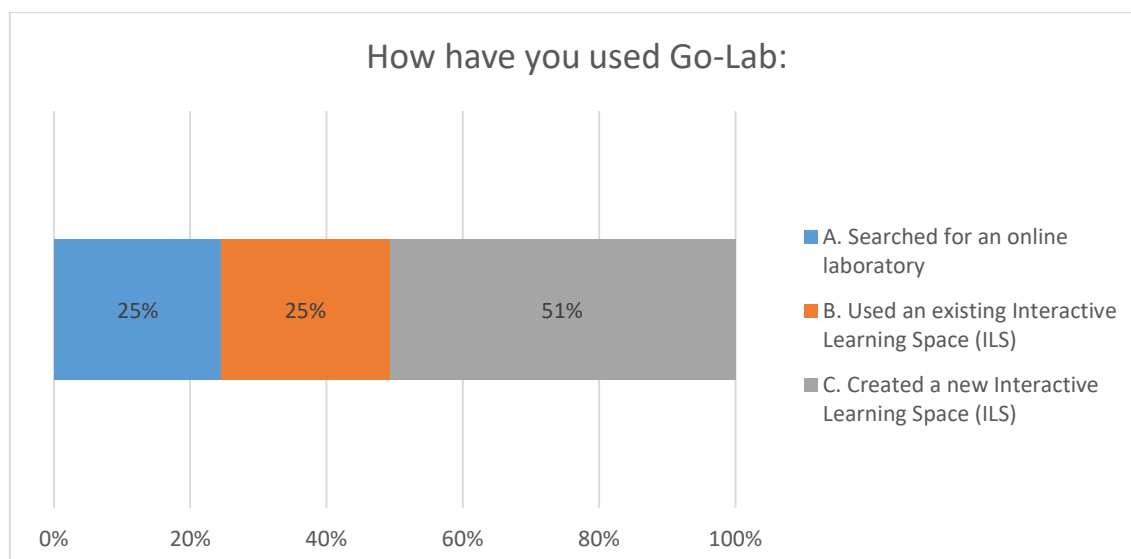
Figure 6. How have teachers used Go-Lab (2015 Survey, D8.3).

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[1] See http://en.wikipedia.org/wiki/1%25_rule_%28Internet_culture%29

A comparison between Figure 6 and Figure 5 reveals that when it comes to the use of Go-Lab, teachers have exceeded their own expectations. In Figure 5, 48% of the teachers were planning to use Go-Lab Portal for finding on-line laboratories and for using existing laboratories with a small number of teachers declaring their intention to create their own ILS. Figure 6 shows a totally reversed use of Go-Lab with the majority of teachers, 51%, moving to a more active use of Go-Lab and creating their own ILS.

Figure 7 demonstrates the timing of the teachers' familiarization with the tools offered by the Go-Lab ecosystem. The teachers support mechanism is in place while a large number of on-line labs and inquiry learning spaces are available to the Go-Lab users. When the integrated system is in operation the teachers are becoming creators of their own activities and they are driving the system developments and the population of the inventory. Among the inquiry learning spaces creators 65% have created 1-3 inquiry learning spaces, 31% 4-7 inquiry learning spaces and 4% more than 8 Inquiry Learning spaces (see Figure 8).

Figure 7. The timing of the teachers' familiarization with the Go-Lab tools. Initially, teachers are registering and exploring the Go-Lab portal tools and facilities after some time a significant number of them will become progressively content creators.

> **The returning user – Krzysztof Rochowicz (Poland)**
>
> Krzysztof Rochowicz is a physics teacher from Poland and a regular Go-Lab user. He has participated and won the Go-Lab contest three times and has attended equal number of summer schools. He has created three ILSs and made eight in-class implementations with them. In addition, he is using other users' ILSs as recommended additional material for his teachers to work with at home. According to his experience the in-class implementations take around one additional didactical hour compared to what he had originally anticipated due to the fact that students tended to use the lab more time than he had thought. He has presented his Go-Lab work in conferences and teachers' meetings.

Finally the Go-Lab consortium has performed a detailed analysis of the web analytics of the Go-Lab authoring environment to assess the effectiveness of the support mechanism that was in place to support teachers work with the system. This study took place in 2015. We can clearly see that the average number of page views is increasing over time as teachers are getting familiarize with the system while at the same time they are receiving effective support through different channels (workshops, on-line help, tutoring platform, summer schools). We estimate that users who are just exploring the platform are making on average 2 page views on the platform, while the ones who are creating inquiry learning spaces are making at least 6 page views (creation plus one-page view per phase of the inquiry activity). The average number of page views is increasing significantly and approaching the optimum use of inquiry learning spaces creators (Figure 9).

How many ILSs (Inquiry Learning Space) on Graasp have you created that have been used in an educational setting?
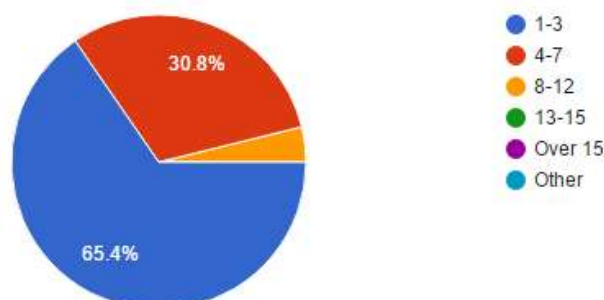
Figure 8. User-generated Inquiry Learning Spaces production distribution.

Effective community support and teachers PD:
Towards the development of a community of content creators

Figure 9. The average number of page views of the Go-Lab authoring environment in relation to the optimum use of using existing inquiry learning spaces (cloning, 2 page views) and the optimum use of inquiry learning spaces creation (min 6 page views) (D6.5).

4. Design for Every Classroom

During the last year of the project implementation (Academic Year 2015-2016) we had the chance to monitor the project work in the classroom. The system was stable and mature and numerous high quality inquiry activities were available. In this period more teachers are producing complete and better ILSs and also actually using them with their students. Now there are 340 ILSs published on the Go-Lab portal (more than 90% of them made by teachers) in various languages and subjects and more than 1000 (precisely 1022) are in use but unpublished.
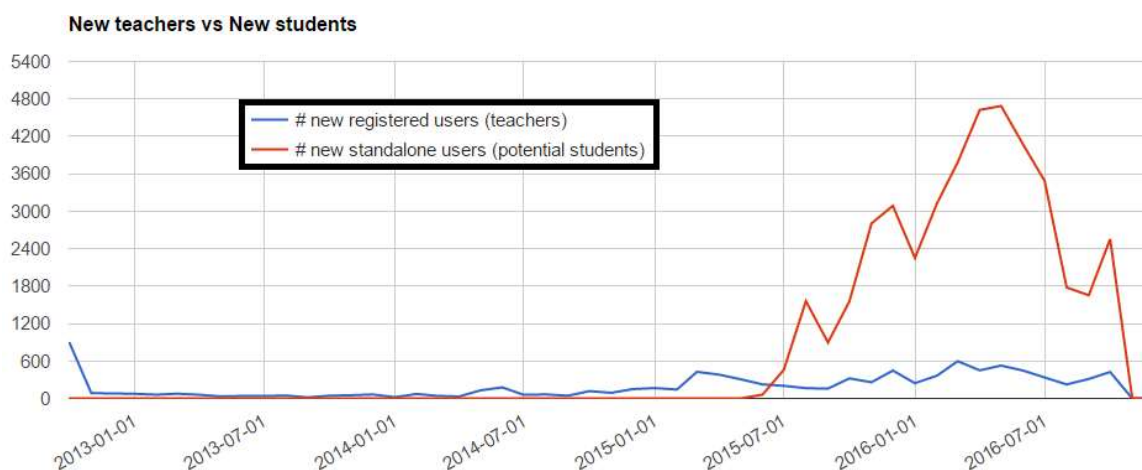
Figure 10. The average number of students in the Go-Lab classroom is 10. The ration between teachers and students remains the same during the different periods. This is due to the fact that in each Go-lab school there are on average 10 devices available for students' use.

The analysis of the system usage data shows nice and wide uptake of Go-Lab approach.

Developing a system for large scale implementation in different European countries is a major challenge. Go-Lab infrastructure was developed in such a way to cope with different classroom settings as well as with different classroom sizes. It has to be noted though that the classroom size in the different analyses performed refers to the number of computers used during the lesson rather to the number of students. The Go-Lab classroom has on average 10 students (access devices), still there were numerous implementations with more students (access devices). As an example a graph of data until 31st May 2016 are presented in Figure 11. The graph shows the number of ILSs versus how many times they are implemented considering different sizes of classroom, i.e. 7 or 10 or 15 standalone users. We observe that in total an estimate of 550-750 ILSs are implemented with an average of about 50% of cases are one time, about 30% are 2-3 times, about 11% are 4-6 times, about 8% are more than 7 times.

This analysis demonstrates that both curriculum developers and on-line lab providers should have a clear view of the school settings where such interventions are taking place. The main characteristics of the system, its functionalities and as well as the approach that it facilitates have to take into account the classroom reality. Again the open structure and the modular approach of systems like the Go-Lab could help teacher to easily adopt the proposed interventions into their classroom settings.
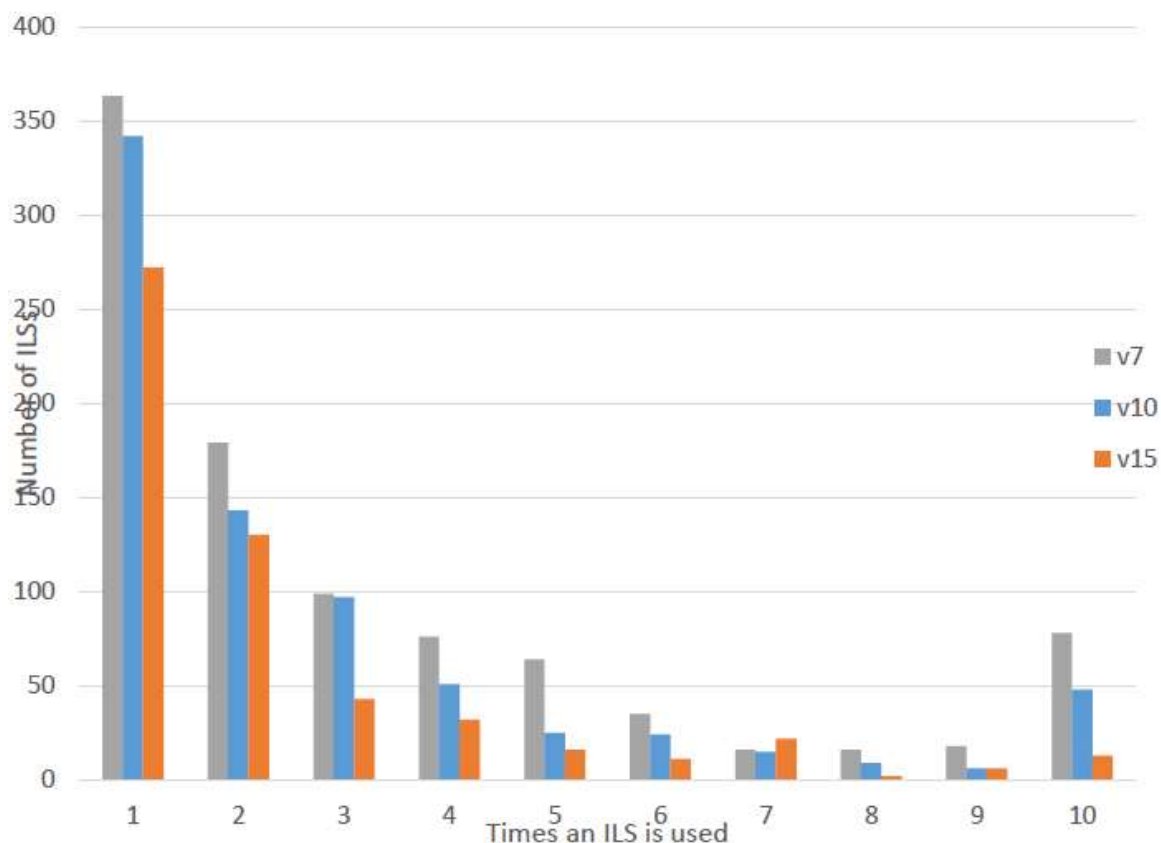
Figure 11. The frequencies of the ILSs used with different classroom sizes (larger availability of devices) (D6.7).
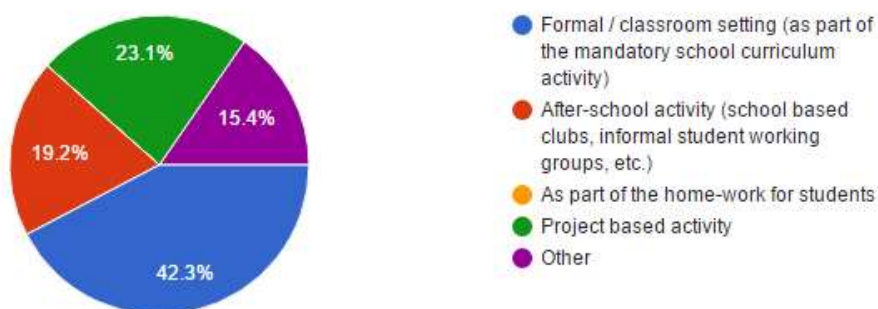
Figure 12. Only 42% of the Go-Lab implementations took place during the school main programme (till 15.00). The rest of the implementations were after school projects (44%) or other related activities (15%).

The large scale experimentation in more than 1000 European schools (in primary and secondary schools, in urban and rural settings, in different educational systems) has offered the opportunity to the consortium to exploit the different faces of Go-Lab. This was done thanks to the active engagement of the teachers who took the initiative to explore innovative ways for its use. Go-Lab was used (see Figure 12) in the framework of the normal lesson

adjusted to different timetables (one or more lesson hours), in the framework of project work that could last for weeks, in the framework of out of school activities as well as for integration of lab work in the final exams (pilot application in Greece with the support of the Institute of Educational Policy of the Ministry of Education).

The many faces of Go-Lab – Carmen Diez (Spain)

Carmen Diez is one of the most active users of Go-Lab. She was introduced to Go-Lab in the early stages of the project and since then she has contributed not only numerous activities but also valuable feedback on the use of the Go-Lab platform and services. Carmen has created eight ILSs, three in English and five in Spanish. So far she has implemented these ILS 14 times in total while she also did one implementation using an ILS from another teacher. One interesting aspect of her work is that she has used the Go-Lab ILSs in many different ways. She has used Go-Lab ILSs in her class as part of her ordinary lesson but she has also extend their use in after school activities, in STEM Project-based activities in a family library and she has also used them to train other teachers on how to use the Go-Lab tools and services. According to her view, the duration of an ILS was equal to the time she had planned to allocate when each student worked with a computer. However, her ILSs seemed to also take a shorter amount of time when working with a limited number pairs of students. She has already presented her work in numerous conferences and has also published articles presenting her collaboration with other teachers in the framework of Go-Lab. Finally, Carmen is a tutor in the Go-Lab tutoring platform and has initiated webinars for teachers on the use of the Go-Lab tools.

5. Effective and systematic Organisation of the on-line labs

The Go-Lab project was set out to create a federation of on-line labs in order to make available to schools throughout Europe and beyond. To achieve that the Go-Lab team has implemented a four-stage deployment cycle by the end of which the Go-Lab inventory was populated with four hundred and three on-line labs which cover the entire STEM spectrum. The on-line labs target a wider range of students' ages, from 6 to 18 years old. The aim of this section is not to present the Go-Lab inventory as this has been done in another specific document of the Go-Lab project, namely deliverable D2.4, "The Go-Lab Inventory and Integration of Online Labs – Complete version". The aim of this section is to present the methodology that was adopted in order to organise the contents of the inventory in a way that will support the effective integration of the on-line labs to the school curriculum while at the same time will facilitate the easy retrieval of labs for the development of Inquiry Learning Spaces that can support the progressive development of students' knowledge.

Defining a relevant set of big ideas of science and positioning the on-line labs on this set was a major pedagogical innovation in Go-Lab project. Furthermore, the inquiry learning spaces have been developed in such a way that they are modular enough to be easily included, that they are adaptable so that they can be adjusted to a certain extend to the curriculum, and that they are tagged with appropriate metadata so that teachers can find the on-line labs that fit their needs. These actions were based on curriculum and teachers' competences analysis that were carried out in the project. The project has designed one overarching approach to ensure that inquiry learning spaces will find their way into curricula of different countries. This will help teacher to place an on-line lab at the correct place in the curriculum.

5.1 Beyond Curricula Restrictions: The Big Ideas of Science

There is growing evidence that inquiry learning and experimentation has a positive influence on attitudes to science. However, it is optimistic to assume that change in pedagogy can be brought about without changing content or the curriculum. Inquiry-based teaching is demanding, both of teachers' skill and of time for teaching and learning. Inquiry-based learning can lead to greater depth in understanding but as it takes more time and the corollary is that the breadth has to be reduced. To facilitate the effective introduction of labs in the curriculum and to promote inquiry learning the Go-Lab team has decided to organize the contents of the inventory following an innovative approach that is based on the "Big Ideas of Science". Thus identifying big ideas of science is a natural, and indeed necessary, accompaniment to promoting inquiry--based science education.

The starting point of our work was the "Principles and Big Ideas in Science Education" report by Wynne Harlen et al. in 2010. The primary objective was to examine whether the set of the ten principles presented could be used to organize the content of the Go-Lab repository. To do that, we began by mapping the science vocabulary used in the Go-Lab repository that was developed under the Open Discovery Project (ODS Project – D4.2) to the ten big ideas of science mentioned in the report. During this process we found out that certain science terms were not fully covered by the current set ten ideas. To this end, we decided to review several similar other sets from the bibliography (on science as a whole or on each science discipline separately) and propose our own "Big Ideas of Science" set. The

produced set was used so as to propose a new methodology for organizing on-line labs and inquiry activities in the framework of the Go-Lab project (Zervas, Kalamatianos, Tsourlidaki, Sotiriou & Sampson, 2014). Based on the definition used, the term "Big Ideas of Science" refers to "a set of cross-cutting scientific concepts that describe the world around us and allow us to conceive the connection between different natural phenomena". (Zervas, Kalamatianos, Tsourlidaki, Sotiriou & Sampson, 2014; Dikke et al., 2014).

After the Big Ideas of Science set was adopted, we mapped it again towards the Go-Lab science vocabulary to make sure that it covered all science terms included. Once that was done we set out to test its usability for organizing on-line labs and inquiry activities. The set was validated with 368 science teachers and teacher trainers to make sure that it can really facilitate the school based work. The initial and updated Go-Lab "Big Ideas of Science" set are presented on Table 1.

Table 1. The updated set of the Go-Lab set of "Big Ideas of Science".

Initial Go-Lab "Big Ideas of Science" set	*Updated Go-Lab "Big Ideas of Science" set*
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.	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.	2. There are four fundamental interactions/ forces in nature. Gravitation, electromagnetism, strong-nuclear and weak nuclear. All phenomena are due to the presence of one or more of these interactions. Forces act on objects and can act at a distance through a respective physical field causing a change in motion or in the state of matter.
3. The Universe is comprised of billions of galaxies each of which contains billions of stars and other celestial objects. Earth is a very small part of the Universe.	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.	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. All matter and radiation exhibit both wave and particle properties.	5. In very small scales our world is subjected to the laws of quantum mechanics.

Initial Go-Lab "Big Ideas of Science" set	Updated Go-Lab "Big Ideas of Science" set
	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.	6. Evolution is the basis for both the unity of life and the biodiversity of organisms (living and extinct). Organisms pass on genetic information from one generation to another.
7. Organisms are organized on a cellular basis and require a supply of energy and materials. All life forms on our planet are based on a common key component.	7. Cells are the fundamental unit of life. 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 shapes the climate and the surface of the planet.	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.
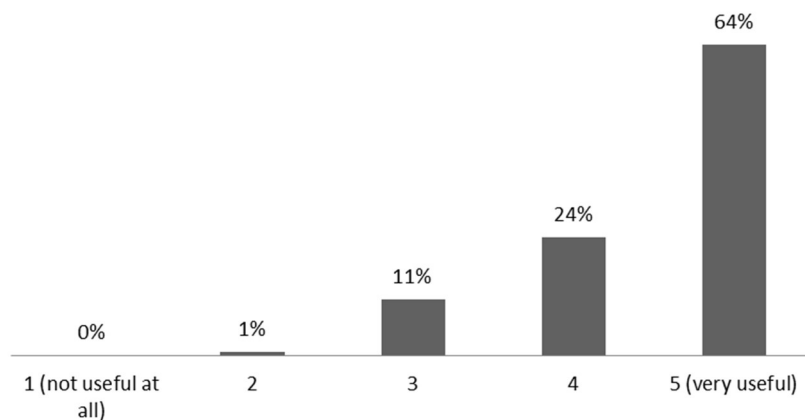
Figure 13. Participants' opinion on the usefulness of a "Big Ideas of Science" recommendation system.

The proposed organizational scheme was discussed with teachers and curriculum developers in many countries across Europe. The feedback received (see Figure 13) was very positive, as 88% of the participants believe that such a recommendation system could be useful or very useful for the development of an inventory of on-line labs.

Overall, teachers' answers and comments during discussions indicate that, in their everyday practice, they are not provided with the means that will allow them to collaborate effectively and be in position to work on an interdisciplinary frame work that allows them to make connections between science subjects and everyday life. According to them, a 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.

The organization of on-line labs in such a scheme offers unique opportunities for the progressive introduction of students to more complex phenomena or concepts. Teachers have the opportunity to design sequences of on-line labs and involve their students in extended learning experiences. Such approaches could support the development of students' problem solving competence, increase students' motivation towards science, parameters which are related with possible careers options in the future.

Finally, the stakeholders' (policy makers and curriculum developers) interviewed believe that the presence of interdisciplinary activities in a science curriculum can be very beneficial for students. In addition, the "Big Ideas of Science" could play a significant role in organizing content and interdisciplinary activities while it could facilitate students in making stronger and deeper connections between facts, concept and phenomena coming from the same or different science disciplines. However, the introduction of such an approach would require properly designed materials for students and a training framework for teachers.

Lastly, one important observation coming from stakeholders is that the organization of science content using the "Big Ideas of Science" that goes beyond curricula could be a useful tool for teachers as it is unaffected by the constant changes that occur in the science curricula of many countries.

5.2   Go-Lab On-line labs Characteristics

Having a closer look to the analysis for the on-line labs' characteristics, presented in deliverable D2.4, we can make the following observations:

a. Lab type*: Virtual Labs is the dominant type of labs (82%)*
Having a much higher number of virtual labs was expected. Compared to remote labs and data sets, virtual labs for science education are much more widely available. This is due to many reasons some of which are listed below:
- Virtual labs are relatively easy and inexpensive to build and do not require constant maintenance.;
- Virtual labs can also be used as tools to help students visualize phenomena that are invisible.;
- Virtual labs can simulate experiment that in real life would take a lot of time to do.
- Virtual labs can facilitate multiple users at the same time.
- Remote labs are very costly to build and they require constant maintenance.
- Remote labs cannot easily support multiple users simultaneously.
- Remote labs often require booking so they may not be available when a teacher needs them.
- Data sets often need additional software to be installed in order to be able to manipulate data.

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

b. **Age Range:** Ages between12 and 18 years old are the ones best represented in the Go-Lab inventory. Ages between 10 and 12 years old are also covered by a significant number of labs.

c. **Subject Domain:** Physics (221) is the most dominant subject domain followed by chemistry (76). Other subject domains include between 25 and 47 on-line labs.

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

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

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

e. **Multilingualism:** English covers 99% of the repository. All languages covered by the consortium are present in the repository. In total, 28 languages have a selection of more than 10 on-line labs.

In an international repository, it is only expected that the vast majority of labs are available in English. This is also the case with the Go-Lab repository. In addition to that, the project tried to include as many multilingual labs as possible focusing mostly on the languages of the implementation countries. Indeed for the languages of the consortium available labs on local languages cover from 25 to 40 for languages that are spoken in one or two countries and from 60 to 80 for languages that are spoken on multiple countries.

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

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

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

Low interaction level means that students manipulated only one variable during experimentation and focused more on observation. Medium interaction level means that the student has to manipulate 2 to 3 variables during experimentation while high interaction indicates the manipulation of more than 3 variables. Thus, in order to have labs that promote problem solving skills and inquiry skills as much as possible, the Go on-line labs would have to be between high and medium level of interaction for their majority.

6. Supporting Teachers to use On-line Labs in the classroom

6.1 Teachers' Support

Go-Lab has successfully identified unfulfilled professional development / support needs and requests, defined the target users and final beneficiaries (students) and clearly identified the main existing challenges. With this information in hand a strategy and timeline had been developed in order to achieve the proposed goals. In Go-Lab this strategy has taken the form of **engagement and training activities,** the construction of a **support mechanism** and a **recognition system** that will keep the community of users engaged and motivated.

In our view there are two main focus areas in the development of such a support mechanism:

- **Providing effective training on inquiry based methods and on the use of on-line labs:** Albeit very effective, inquiry-based methods in science education constitute a major paradigm shift for teachers: they need to acquire new skills, abandon long standing practices and move away from their professional "comfort zone", therefore exposing themselves to perceived, or real risks.
- **Assisting behavioural change:** Apart from their training, in order for teachers to introduce both inquiry based methods and on-line labs into their everyday routine, they need to undergo a change in behaviour and adapt a new culture and philosophy. In order for the Go-Lab approach to assist this change, we introduced a solid theoretical framework and underlined the main actions that need to be taken.

Asking teachers to follow inquiry-based methods and using on-line labs in their everyday teaching practice constitutes a major behavioural change and at the same time a significant development opportunity for them. The task at hand is to manage this change in a uniform way, allowing teachers to realize the potential of the opportunity offered by the Go-Lab project, take ownership of their contribution and maximize the output for both the project and themselves. One of the ways to attain the goals of inquiry learning is to treat teachers as equal partners in decision making. In other words, teachers have to play a greater role in providing key leadership at all levels of the educational system. Leadership in the context of science education was defined as the ability of a person to bring changes among teachers and teaching.

The "teacher as a leader" strategy can provide an effective mechanism for disseminating innovative instructional strategies like inquiry based approaches from central to regional locations (e.g. national teacher centres to regional centres, school-based programs).

In this approach the central agents of this operation are "teacher-leaders", who head the transformation processes at the local level. This model has been used in networks involving national and regional teacher centres. The leader teachers undertook a variety of regional activities, such as, guiding teachers in regional centres or in schools, and providing guidance for both teams and individual teachers (Pratt, 2001). Pratt (2001) suggested that that there are four basic skills relevant to effective leaders in science education namely; (1) technical skills, (2) conceptual skills, (3) interpersonal skills, and (4) self-learning skills. Programs for teachers-leaders are designed to help acquiring these skills and help them choose and/or design models for programs they will run later with other teachers. The professional development program can also provide the teachers with a framework for the

initial preparation of tools necessary for running their own activities. When teachers-leaders participate in PD programs that deal with innovation, as with other teachers they experience the innovative strategy both as students and as teachers, but in addition acquire guiding skills in the particular area.

Teachers as Go-Lab ambassadors and multiplier actors: Panagiota Argiri (Greece)

It is often the case that Go-Lab teachers take up the initiative to become Go-Lab ambassadors and disseminate the use of the Go-Lab infrastructure to other teachers and other schools. One such teacher is Panagiota Argiri from Greece. Panagiota has been using Go-Lab for two years; she started by implementing other users' ILSs in her class and continued with making 15 ILSs of her own. Although she is a mathematics teacher of secondary education, the topics of her ILSs vary from complex physics ILSs to simple astronomy ILSs for young pupils. So far she has implemented eight different ILSs with her students in the framework of after-school project-based activities while she has also done seven more in-class implementations. In addition, she has done 32 more implementations in different Greek schools in collaboration with other teachers. In her first implementations, ILSs would take 30 to 45 more minutes than expected but after a few times the duration was as she had expected. So far she has presented her work in four different events and conferences.

In all cases of such a professional development programme there is special emphasis on building a network of the teachers that would form a community of practice. In a review paper (Emily Lawson and Colin Price, 2003), McKinsey management experts identify four key prerequisites for accelerating and establishing change in the school environment:

- **A purpose to believe in: "I will change if I believe I should"** .The first, and most important, condition for change is identifying a purpose to believe in. In our case, we must persuade teachers of the importance of scientific literature in terms of social value, importance to their students and personal achievement through learning and teaching these important subjects. We must carefully craft a "change story" underlining the benefits that the project can offer to all the involved actors. Furthermore, we must cultivate a sense of community, making the teacher feel part of a cohesive multi-national team. This sense of belonging will prove very important for motivating teachers and asking them to take then next, possibly "painful" steps, of learning new skills.

- **Reinforcement systems: "I will change if I have something to win".** From a pure behaviouristic point of view, changing is only possible if formal and informal conditioning mechanisms are in place. These mechanisms can reinforce the new behaviour, penalize the old one or, preferably do both. In our case, we can use informal reinforcement patterns in order to make teachers commit more to our project. A short list of such methods could include competitions, challenges, promoting the best teacher created project or lesson plan, offering e.g. the participation to a summer school as rewards.

- **The skills required for change: "I will change if I have the right skills".** A change is only possible if all the involved actors have the right set of skills. In the case of the

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Go-Lab project, we should make sure that our training program is designed in such a way that teachers acquire all the skills they will need, both technical and pedagogical.

- **Consistent role models: "I will change if other people change".** A number of "change leaders" will need to be established, acting as role models for the community of teachers. These very active and competent teachers will be a proof of concept for their colleagues that the change is indeed feasible, acceptable and beneficial for them. To achieve that we will have to identify the high flyers among the participating teachers and pay special attention into motivating them, supporting and encouraging them.

All four have specifically been addressed in each implementation phase of the Go-Lab project. Additionally, the consortium team has collaborated closely with teachers to develop a set of support services which helped teachers to implement the necessary changes, to develop the diagnostics and intervention skills necessary to best plan and then diffuse IBSE and the use of on-line labs in their own contexts.

The cascade effect -Teachers Training Teachers: From Ivo to Tsetsa, to Boryana (Bulgaria)

Tracing back the line of how teachers were first introduced to Go-Lab can give us some interesting insight that demonstrates the cascade effect that is present in some of the Go-Lab implementation countries. One such case is found in Bulgaria. Physics teacher Ivo Jokin was first introduced to Go-Lab in 2014 when he participated (and won) in the first Go-Lab contest and was invited to attend the second Go-Lab summer school. Since then, Ivo did not limit his Go-Lab activities in class. Instead he took up the initiative to introduce Go-Lab to other Bulgarian teachers. As a result many other Bulgarian teachers were involved in Go-Lab and in next year's contest. Tsetsa Hristova, was one of the teachers who learned about Go-Lab in a workshop organized by Ivo and she decided to participate in the contest as well. In 2015, it was Tsetsa's turn to enter and win the Go-Lab contest in Bulgaria and participate in the third Go-Lab summer school. After her training in the summer school, Tsetsa continued collaborating with Ivo and she also joined the initiative to organize additional workshops in Bulgaria. In the fourth year of Go-Lab, partners realized one more training workshop in Bulgaria with the help of Ivo and Tsetsa at the beginning of April 2016. One of the teachers participating in this workshop was Boryana Kujumdzhieva. Although the deadline of the contest was a few weeks away, Boryana took an existing ILS, adapted it to match the needs of her students, and she used it as homework for them. She submitted the implementation she did to the contest and won. In the next two months she created three ILSs of her own and also presented the work she had done in the 2016 UNESCO International Workshop. Finally as a contest winner she too participated in a Go-Lab summer school and plans to do at least 10 implementations in the coming year using Go-Lab ILSs.

Moreover, within Go-Lab we have developed an effective training approach that provided the starting point for equipping teachers with the competences they need to act successfully as change agents, developing a language/terminology necessary to describe the dynamics of change processes, and making them able to recognize different forms of resistance and addressing it in their own context. At the same time, it has provided a common basis/experience for "connecting" teachers across schools, within and across national boundaries – engaging them in an ongoing exchange of experiences across school, regions and countries.

6.2 Developing Communities of Practice

There are severe constrains that are being faced by educators while trying to introduce innovation in their classrooms. Teachers have little time to explore new tools and new trends; they have in general dense and extensive curricula to follow and the continuous pressure to prepare students for final exams.

Our framework has taken all these issues into account and was trying to find the best compromise between the possibilities available in Go-Lab and the existing constrains in the school context in order to meet teacher's needs. Here we try to describe both the priorities and the strategy adopted in order to have a real contribution of Go-Lab for the professional development of teachers.

Table 2. The 5 pillars for the sustainability of Go-Lab communities.

Engagement	Training	Support	Recognition	Community
Visionary Workshops	Face-2-face training	Support Platform	Certification	Pilots communities
Practice Reflection Workshops	on-line – MOOCs, webinars	On-line Support	Accreditation	Pilots Mailing list
On-line Activities	International /National schools	Demo activities in schools	Digital Badges	Pilot's cascade
		Pilots Days		

In Table 2 we present the 5 pillars sustaining the construction of the Go-Lab virtual community and ensuring its continuation and sustainability:

- **Engagement Activities** – A series of opportunities to engage schools and teachers on the use of Go-Lab. The main objective of this first pillar is to create awareness about the existence of the project, to reflect with users on the usability of the overall structures, support the adaptation/localization efforts and provide a sense of ownership and partnership to those piloting the first stages of the construction of this community.
- **Training Activities** – The virtual community of users is composed by those that are making maximum use of the system. Training events are a core activity promoted

and coordinated by WP7 and ensuring that teachers have the opportunity to explore the whole proposal and benefit from immediate support coming from the Go-Lab team and/or from pilot teachers already proficient on the use of the project proposed methods and tools.

- **Support Activities** – A strong help desk where teachers can find the necessary support for their immediate questions or for long term implementation efforts is the heart of the sustainability of Go-Lab. To ensure that this mechanism is in place WP6 has been developing a series of actions to create a support hub and a peer to peer support platform. Demo activities and pilot days have been implemented to ensure the adaptation of specific needs and the active collaboration of all stakeholders in the field.
- **Recognition Activities** - Certification and accreditation are an integral part of teachers' professional development. With this vision in mind Go-Lab has started taking all necessary steps to develop an efficient recognition mechanism that will validate the participation of all teachers and eventually recognize their support according to the different levels of commitment.
- **Community Activities** – This is the part that has ensured the effectiveness and will play a decisive role in the future sustainability of the project. The size of the community and its level of engagement are the best indicator of the success of Go-Lab. The necessary mechanisms to support the creation and continuation of this virtual community are the key aspects of this pillar.

6.3 Go-Lab Teachers Academy: A Common Exploitation Plan for the Go-Lab National Coordinators

At the core of the Go-Lab exploitation strategy is the **Teachers Professional Development Programme.** The programme is focusing on school leaders, instructional leaders and innovative teachers who are developing innovative scenarios and projects using Go-Lab tools and resources. Facilitating the **Go-Lab Tool Box** (a series of guidelines, manuals, videos, scenarios of practice, tools and show cases from the numerous Go-Lab schools) the programme can support participants to introduce innovative aspects in their science classroom settings. The programme is offered by the **Go-Lab Academy (Go-Lab.ea.gr)** in the form of webinars, interactive on-line sessions, 2 to 6 day long courses and field visits and observations in Go-Lab schools all over Europe (currently more than 1500 schools in 15 European countries).

The full six-day course is offered to teachers since 2013 in Greece, in UK and in the Netherlands with more than 200 teachers from 20 countries taking part so far. Shorter versions of the course have also been offered to teachers in different European countries and mainly in Spain and Portugal. An on-line version of the course (in the form of a MOOC) is currently implemented. The programme will include a series of hangouts that will support content development and scenario authoring in different local, national and international participant communities. The tools and the infrastructure is offered by the Go-Lab Community Support Environment.

Go-Lab has developed an innovative mechanism to engage regularly with the numerous Go-Lab Schools in order to support their needs and their further development. The project team design and offer customized courses that can support specific school needs.

At the end of the project in November 2016, the work on mainstreaming Go-Lab outcomes will be taken forward by the 10 National Coordinators at national level. Through the advanced delivery approach of the Go-Lab Academy numerous courses on school science will be supported at local, national and international level.

The Go-Lab Academy has already successfully established itself as a facility that showcases innovative scenarios of school reforms, and provides professional development courses and workshops. Furthermore the Go-Lab Academy organizes field observations and offers job shadowing opportunities for the participants in numerous European schools.

The consortium of the 10 National Coordinators in cooperation with the technical team can offer numerous professional development opportunities for the whole period of the Erasmus + programme (2014-2020).The consortium of the 10 National Coordinators will support schools in this process. The consortium will develop a support mechanism for schools to training their teachers in the framework of the Go-Lab project. Making the assumption of 4 courses with 25 participants are organized per year in each country, the Go-Lab Academy can offer a minimum number of 40 courses per year, offering training to 1,000 teacher leaders, school leaders and innovative science teachers per year.

7. Go-Lab Framework for the introduction of on-line labs in school classrooms

In this chapter, we are summarizing the recommendations for the introduction of on-line labs in schools. Initially, we are proposing a series of design considerations. We are presenting series of strands according to our view that the curriculum developers but mainly the on-line lab providers (as well as outreach teams of research infrastructures or universities) should have in mind when designing or developing on-line labs to be used in educational settings.

The recommendations for the introduction of on-line labs in the classrooms reflect the findings and the lessons learnt from the large scale implementation that took place in the framework of the Go-Lab project. The recommendations were discussed in the previous chapters, while a series of supportive findings or examples were presented.

7.1 Design Considerations: Strands and Educational Objectives of on-line labs

In order to capture the multifaceted nature of science learning, the Go-Lab approach proposes – additionally to the set of the recommendations, a roadmap that includes series of strands for the design and development of on-line labs for schools and articulates the science-specific capabilities supported by the Go-Lab environment. This framework builds on a four-strand model developed to capture what it means to learn science in school settings[xxi] by adding two additional main strands incorporated for informal science learning, reflecting a special commitment to interest, personal growth, and sustained engagement that is the hallmark of informal settings.

Table 3. The main strands and the Educational Objectives for the design and development of on-line labs for involving students in inquiry learning.

Strands	Educational Objectives
Igniting Interest and Excitement	*Experiencing excitement, interest, and motivation to learn about phenomena in the natural and physical world.*
Understanding Scientific Content and Knowledge	*Generating, understanding, remembering, and using concepts, explanations, arguments, models, and facts related to science.*
Engaging in Scientific Reasoning	*Manipulating, testing, exploring, predicting, questioning, observing, analyzing, and making sense of the natural and physical world.*
Reflecting on Science	*Reflecting on science as a way of knowing, including the processes, concepts, and institutions of science. It also involves reflection on the learner's own process of understanding natural phenomena and the scientific explanations for them.*
Using the Tools and Language of Science	*Participation in scientific activities and learning practices, using scientific language and tools.*
Identifying with the Scientific Enterprise	*Coming to think of oneself as a science learner and developing an identity as someone who knows about, uses, and sometimes contributes to science.*

Sparking Interest and Excitement

The motivation to learn science, emotional engagement, curiosity, and willingness to persevere through complicated scientific ideas and procedures over time are all important aspects of learning science[xxii]. Recent research shows that the emotions associated with interest are a major factor in thinking and learning, helping people learn as well as helping them retain and remember[xxiii]. Engagement can trigger motivation, which leads a learner to seek out additional ways to learn more about a topic. In the framework of the Go-Lab project we have managed to offer numerous such activities to the participating schools. Virtual visits to unique scientific experiments (CERN, IceCube, NESTOR, LIGO) were organised to spark the interest and to increase the excitement of the students.

Understanding Scientific Content and Knowledge

This strand includes knowing, using, and interpreting scientific explanations of the natural and physical world. Students who are visiting (virtually in our case) advanced research infrastructures come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science. Students also must understand interrelations among central scientific concepts and use them to build and critique scientific arguments. While this strand includes what is usually categorized as content, it focuses on concepts and the link between them rather than on discrete facts. It also involves the ability to use this knowledge in one's own life. In the framework of Go-Lab project we had the unique chance to follow closely the huge increase of interest of students on High Energy topics after the announcement of the Nobel Prize for the discovery of Higgs in November 2014. Effective outreach programmes and on-line labs could provide great tools for the teachers who have to cope with an increased number of student's questions on such complex topics.

Engaging in Scientific Reasoning

This strand encompasses the knowledge and skills needed to reason about evidence and to design and analyze investigations. It includes evaluating evidence and constructing and defending arguments based on evidence. The strand also includes recognizing when there is insufficient evidence to draw a conclusion and determining what kind of additional data are needed. Many informal environments provide students with opportunities to manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world. In fact, most outreach and educational activities have to be built around the concept of exploration. Usually visitors (physical or virtual) are not given a correct scientific explanation of a natural phenomenon. Rather, they are presented with a phenomenon and then led through a process of asking questions and arriving at their own answers (which may then be verified against current scientific explanations). The generation and explanation of evidence is at the core of scientific practice; scientists are constantly refining theories and constructing new models based on observations and empirical data. Understanding the connections, similarities, and differences between the ways people evaluate evidence in their daily lives and the practice of science is also part of this strand (e.g., understanding the impact of individual and collective decisions related to light pollution, understanding the use of advanced technological applications to everyday life). Through trial and error, students can begin to develop a deeper understanding of the world. The Go-Lab tools have enriched the existing on-line labs with numerous functionalities that offered an integrated and effective learning experience to the students involved.

Reflecting on Science

The practice of science is a dynamic process, based on the continual evaluation of new evidence and the reassessment of old ideas. In this way, scientists are constantly modifying their view of the world. Students reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena. This strand also includes an appreciation of how the thinking of scientists and scientific communities' changes over time as well as the students' sense of how his or her own thinking changes. Research shows that, in general, people do not have a very good understanding of the nature of science and how scientific knowledge accumulates and advances[xxiv.] This limited understanding may be due, in part, to a lack of exposure to opportunities to learn about how scientific knowledge is constructed and how scientific work is organised[xxv]. It is also the case that simply carrying out scientific investigations does not automatically lead to an understanding of the nature of science. Instead, educational experiences must be designed to communicate this explicitly. Also compelling are the human stories behind great scientific discoveries.

Using the Tools and Language of Science

The myth of science as a solitary endeavour is misleading. Science is a social process, in which people with knowledge of the language, tools, and core values of the community come together to achieve a greater understanding of the world. The story of the discovery of Higgs boson (July 2012) is a good example of how scientists with different areas of expertise and from numerous nations around the world came together to accomplish a Herculean task that no single scientist (not even a large research laboratory) could have completed on his or her own. Even small research projects are often tackled by teams of researchers. Through participation in informal environments, non-scientists can develop a greater appreciation of how scientists work together and the specialized language and tools they have developed (among them the web that was developed at CERN to support international cooperation in research topics). In turn, students also can refine their own mastery of the language and tools of science. For example, teachers participating in the CERN High School Teachers Training Programme in 2014 come together as a community to solve a particular problem: to develop an innovative and user-friendly game to help their students to get familiarised with the elementary particles properties. Using the tools of science, such as detectors and similar devices in a game-like approach to identify the particles that were produced from a collision, students could become more familiar with the means by which scientists work on their research problems. By engaging in scientific activities, participants also develop greater facility with the language of scientists; terms like hypothesis, experiment, and control begin to appear naturally in their discussion of what they are learning. In these ways, non-scientists begin to gain entry into the culture of the scientific community.

Identifying with the Scientific Enterprise

Through experiences in the framework of outreach and educational programmes, some students may start to change the way they think about themselves and their relationship to science. They think about themselves as science students and develop an identity as someone who knows about, uses, and sometimes contributes to science. When a transformation such as this one takes place, young people may begin to think seriously about a career in a research field, in an engineering firm, or in a research laboratory. Changing individual perspectives about science over the life span is a far-reaching goal of

outreach and educational activities of the major research infrastructures. Sustaining existing science-related identities may be more common than creating new ones.

The strands are statements about what students do when they learn science, reflecting the practical as well as the more abstract, conceptual, and reflective aspects of science learning. The strands also represent important outcomes of science learning. That is, they encompass the knowledge, skills, attitudes, and habits of mind demonstrated by learners who are fully proficient in science. The strands serve as an important resource for guiding the design and development of on-line labs for schools and especially for articulating desired outcomes for learners.

7.2 Implementation Recommendations: Introducing on-line labs in school classrooms

The recommendations and the strands provide a framework for thinking about elements of scientific knowledge and practice. The proposed framework describes a series of support functions that have to be deployed for the long-term impact of the proposed activities to be safeguarded. Such support actions could include support for: the integration and coordination of educational and outreach activities between groups across different research institutions; the science community and scientists interested in educational and outreach activities; the education communities interested in scientific content and applications; special events and activities that provide means and tools for web-based communication and collaboration. This framework provides a useful reference for helping teachers and outreach groups in the informal science education community articulate learning outcomes as they develop training programs, activities, and events, and further explore and exploit the unique benefits of introducing on-line labs in schools.

Table 4. The main recommendations and the proposed actions for the effective introduction of on-line labs in schools.

Main Recommendations	Key Actions
Trust teachers' professionalism	*Involve teachers to the localization of the on-line labs.*
	Involve teachers in the design of educational activities with the on-line labs
	Reward teachers for their work
Design for every classroom	*Take into account the different needs of the schools*
	Design on-line labs to support a variety of learning settings and situations
Organize the on-line labs according to the curriculum needs	*Take into account the curriculum restrictions and the time limitations*
	Describe clearly the on-line labs characteristics. Help teachers to select the most appropriate for their needs. Define clear educational objectives (see also section 7.2)
	Enforce multidisciplinary and progressive introduction to complex phenomena and concepts through a sequence of labs
Support Teachers	*Seek for innovators – Create vision*
	Support community building as a professional development process
	Offer Guidelines and examples of good practices
	Provide continuous support and guidance

Furthermore, such an action asks for knowledge areas integration, effective and closes cross-institutional collaboration, and organizational change in the field of science education. It has to be noted though that the achievement of the high quality science teaching requires the combined and continued support of all involved actors, researchers, policy makers and curriculum developers, science teachers' educators, teachers, students and parents.

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