Go-Lab

Global Online Science Labs for Inquiry Learning at School

Collaborative Project in European Union's Seventh Framework Programme

Grant Agreement no. 317601

Deliverable D6.2

Future Challenges Report

Editors: Claudio Dondi - MENON
Jennifer Palumbo - MENON
Nikos Zygouritsas – MENON
Vasilis Fasoulis – MENON
Spiros Borotis – MENON
Nikitas Kastis - MENON

Date: 30th October 2013

Dissemination Level: Public

Status/Version: Final

The Go-Lab Consortium

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

Contributors

Name	Institution
Claudio Dondi	MENON
Nikos Zygouritsas	MENON
Jennifer Palumbo	MENON
Vasilis Fasoulis	MENON
Spiros Borotis	MENON
Nikitas Kastis	MENON
Evita Tasiopoulou	EUN
Agueda Gras	EUN
Olga Dziabenko	UDEUSTO
Maria Luz Guenaga Gomez	UDEUSTO
Sofoklis Sotiriou	EA
Eleftheria Tsourlidaki	EA
Georgios Mavromanolakis	EA
Evita Tasiopoulou (peer review)	EUN
Elio San Cristobal Ruiz (peer review)	UNED
Ton de Jong (peer review)	UT

Executive Summary

This report describes the results of the WP6 research activities performed in the first year of the Go-Lab Project and represents a Milestone in WP6 – Community Building and Support. It is serving the need for the identification of the current and future challenges as it regards Science Education and the scope and the approach of the Go-Lab Project in order to address them in a holistic and state-of-the-art way. Therefore, the results and the conclusions are presented as a basis for further work. However, participatory engagement and the study of related methodologies will continue during the life-cycle of the project and will allow partners engaged in these parts of the project to periodically update and enrich their work in this domain with new inputs, to go beyond the scope of this deliverable.

For this reason, following the description of the activities performed and the conclusions that can be drawn from this work, the last chapter contains a set of open questions that will remain in the agenda of the project partners and will drive further activities.

The structure of the report is the following: Chapter 2 presents the original hypotheses and the methodology connected, Chapters 3, 4, 5 and 6 present the main results according to the sources and approaches used to collect data and articulate them, Chapter 7 contains an integrated overview of results and, together with the conclusions, presents a list of open issues that the project will continue to address in view of maximising its future impact.

Finally the Six Discussion Papers (Challenge and Opportunities Papers) produced as a main component of this study by WP6 partners are presented in Annex 1, while the list of names of experts interviewed is presented as Annex 2.

The following conclusions are the result of the work reported here:

1. The Future Challenges Study confirms the relevance of the aims and the approach adopted by the Go-Lab Project in terms of its vision for school education in the future and of the potential of the ICTs to contribute to this vision. The project’s specific contribution to the upgrade of Science Education at the European and international level is still considered as significant, while the project's complementarity to a number of large-scale, Europe-wide initiatives, supported by the European Union, coherent among themselves, is seen as timely.
2. There is also a broad consensus on what the main challenges and the main areas of change are. In particular, these include the curricula reform and assessment methods, the competence-based learning and innovative pedagogy as well as the learner-generated knowledge; additionally, the upgrade of teachers’ competences, the motivation and capacity building towards change, the learners motivation as well as the upgrade of teachers' digital competences, their familiarization with the digital technologies and the use of digital resources. Addressing each of these challenges is possible and small-scale experiences exist to demonstrate good practice, yet system-scale innovation is the real challenge.
3. Nevertheless, although it is difficult to address all challenges simultaneously, this still corresponds to the best approach in order to reach the objective of system-scale innovation. Over thirty years of both European and national Programmes aiming at the adoption of ICT in education show that an integrated approach is indispensable in order to produce real impact: technology infrastructure without the enhancement of teachers’ competences and motivation will not change the way Science is taught - or better Science learning is experienced - nor any change in pedagogical practice will ever happen without a change in the way the curriculum is being conceived and built and the learning assessment is being

delivered. It is therefore fundamental that the Go-Lab large scale piloting needs to be supported by the relevant institutions in each participating country and coupled with the above-mentioned principles, if the project is to combine the bottom-up approach of the participating schools with the relevant “innovation policy” framework of the country. The virtuous circle between research, policy and innovative practice must be fully adopted by the project.

4. Stakeholders’ involvement is a crucial element in the project implementation: without stakeholders’ attention and consensus a mechanistic implementation of innovative experiences will not produce significant impact after the end of the project. Stakeholders must not only know about the Go-Lab Project, but also support its efforts, and in order to do this they need to gain “ownership” of the pilot experiences and be allowed to gain an important role in its future implementation.
5. Formative Evaluation and Quality Assurance are two fundamental features of the Go-Lab project because they lead the way so that the partners keep an open and consistent communication channel among WPs and Tasks and, even more importantly, with the stakeholders, and as we have stated this is one of the keys for the maximization of the project's impact in the medium and long term. If we look beyond the project “contractual life” – that is relatively long and already contains quite ambitious quantitative and qualitative objectives - the real success will consist in a large-scale follow up of the project results and their integration into the EU and the national policies for the modernization of Science Education. To reach this goal a systemic and transparent documentation of the working cycle of the project, of difficulties and improvements and of lessons learnt, is of utmost importance.
6. Finally, the Go-Lab Project has a lot of challenges to face in the next couple of years, and at the same time a real and concrete opportunity to become relevant, in view of an anticipated, systemic change of Science Education in Europe. Making this opportunity a reality will depend on the conditions identified above and probably others that will emerge in the coming years of the project. Every one of the identified challenges will need to drive the project activities' planning, while in the meantime, certain important aspects that are still open will be addressed.

Table of Contents

1. Introduction: scoping Future Challenges in Science Education

This report is produced in the framework of the Go-Lab (Global Online Science Labs for Inquiry Learning at School) and summarises the results of a broad range of participatory methods and activities that will lead to stakeholders' engagement in the project. Relevant fieldwork and desk research carried out also aims to identify the main challenges that the future development of project outcomes and learning practices will have to face in view of their full scale development in European school systems.

This work reflects the need, which is well understood already at the conception phase of the Go-Lab project, to comply and contribute, at the same time, to the evolution of new forms of Science Education and the validation of enhanced ICT-Supported schemes for the facilitation of the quality upgrade of the learning experiences, and thus to look forward and to remain flexible –in the proposal of technical, pedagogical and organisational models- and open to new developments and new understanding of the many challenges that partners face in order to reach the level of impact that the project is aiming at.

The report contains the results of the activities performed in the first year of the Go-Lab Project and represents a Milestone in WP6 – Community Building and Support. However, since both the participatory engagement and the prospective analysis continue during the life-cycle of the project, partners engaged in these parts of the project will periodically update and enrich their experience and expertise in the domain with new inputs.

Therefore, this report builds on many different kinds of input and information collected by the project to go further in the implementation and improvement of the methodology for the following stages of work. In the final chapter of this report, a set of open questions have been identified that will remain in the agenda of the project partners and drive further activities.

Six Discussion Papers (Challenge and Opportunities Papers) on different aspects relevant to the project work have been produced in order to allow an in-depth reflection on these issues. Further, interviews have been collected according to a common grid to represent the point of view of respected experts from the field. Lastly, relevant research papers and studies have been collected and analysed in order to form a basis to build on in the following phases of the project.

While some parts of this report are closely related to the core of the Go-Lab project, others, according to the fieldwork results and the literature review, have a broader scope and refer more generally to the impact of ICT on education (school, but also informal learning), and to the transformation of School education processes at large. This double perpective allows to build a dialectic view between a larger scope system and the focus on the concrete project implementation challenges. We believe that this tension between points of view is desirable and even necessary not only to reach an integrated approach to project development, but also to take into account the interest of all relevant stakeholders and thus enhance the potential impact of all project achievements.

2. The starting hypotheses and the approach adopted

In this section the starting points pertaining to the content of this study are outlined and the methodological approach of the study are presented.

2.1 The starting hypotheses of the Go-Lab Project and the connection with the Future Challenges in Science Education

In extreme synthesis, this Future Challenges Study is based on the following set of hypotheses, well identifiable in the Go-Lab rationale and articulation:

1. Science education at school requires substantial improvement in order to meet the needs of the knowledge society.
2. ICT has a very high potential to support innovation in education at large and science education in particular.
3. Inquiry learning is key to improve the learning practices as well as the learning outcomes in science education; however, it needs to be supported by appropriate guidance measures.
4. On-line labs can substantially increase the motivation of learners and the practice of learning by doing experiments.
5. The international exchange of experiences is a multiplier of good practice in the teaching and learning of science.
6. Active involvement of schools and teachers in the production of new learning resources and learning pathways is an effective approach to scale up the project impact.
7. Bottom-up and top-down approaches to innovative practice need to be integrated to achieve system-level impact.

2.2 The Approach Adopted

This report is the result of four types of activities:

- The 25 visionary workshops conducted by the project, in which the teachers' community (490 participants) was consulted on the future of science education, on the Go-Lab approach and on the challenges of such an approach in the context of school systems, thus identifying the main opportunities, but also the main barriers to be overcome;
- The consultation of several other categories of stakeholders through interviews and on-line surveys (in particular science education experts, school leaders, publishers and policy makers);
- The collaborative production of six Challenges and Opportunities Papers, discussion papers that were developed by WP6 partners and respectively exploring six major issues that condition the future development of labs use and inquiry-based learning in European schools;
- The systemic review of scientific literature and parallel projects results on the subject of future science education.

Each of these "methods" to collect stakeholders views and research results has produced significant results that are, respectively, presented in the chapters 3, 4, 5 and 6. Chapter 7 provides an integrated synthesis of all results, some preliminary conclusions and a set of open questions to be further explored by the Go-Lab Project and beyond it; while the full text of the 6 Challenges and Opportunities Papers is presented in Annex 1.

3. Inputs from visionary workshops

In this section, the main results of the 25 visionary workshops conducted in Year 1 are reported: after a reminder of the purpose of these small interactive events, the general feedback on the Go-Lab approach is presented and the focus is then put on the suggestions coming from teachers and the identified set of challenges for the full implementation of the project and its multiplication potential.

3.1 Aims and Implementation of Visionary Workshops

The first set of participatory activities in the Go-Lab Project was the organization of 25 Visionary Workshop the aims of which are briefly described in the following points. A secondary effect of these workshops, which is nonetheless important to mention here because of their relevance and their impact to the project is that, visionary workshops have facilitated the Go-Lab project partners to approach teachers, constituting a preliminary pilot schools recruitment process. This is a further example of the interaction between WP6 and WP7. Thus, the aims of the Visionary Workshops were as follows:

1. To collect stakeholders' views on the future of science education and the specific role that could be played by online laboratories, so as to contribute to the Task 6.1 (Critical Framework Thinking).
2. To collect feedback on the pedagogical, organisational and technological elements of the model initially proposed by the Go-Lab Project and to use this feedback in the development work taking place in year 1, especially as far as the pedagogical framework is concerned.
3. To inform national audiences on the Go-lab project proposal and to contribute to the creation of favourable institutional conditions for the Large-scale Piloting, thus contributing to Dissemination activities of WP9.
4. To establish a productive dialogue with a set of national stakeholders who will accompany the development of the project in its different phases.

Actually, most of the participants were teachers that will most probably be involved in the large scale piloting that will take place from year 2 on within the Go-Lab Project.

An open discussion / debate on the future of science education was not always possible because workshop agendas and concrete development had to be adaptated to the context and the expectations of the participants in the workshops. Nevertheless, significant feedback has been collected on the Go-Lab idea and the methodological approach, and a preliminary list of barriers to large scale implementation was identified.

3.2 Feedback on the Go-Lab approach

The Go-Lab project and its outcomes correspond to certain needs of teachers. In all cases, the project received very positive critics and the participants regarded its (potential) outcomes as valuable. Furthermore, the participants thought that visionary workshops were also interesting and engaging.

Almost all participants tend to believe that a digital repository of online tools would be useful. Most of the teachers appreciated the idea of a federation of good quality laboratories.

The majority of the participants seem to feel comfortable with the proposed Go-Lab working environment. When shown mock-ups of the interfaces that will be used in the platform, most of them agreed that simple graphics and the use of small icons and colours will help them explore services more easily. Teachers liked the design and underlined the need for a simple interface with not much text.

Additionally, the participants agreed that the presence of guidance (including scaffolds) would be valuable and helpful to both teachers and students.

Moreover, most of the participants would recommend the Go-Lab activities to their colleagues, whereas all of them agreed that it would be useful to have access to educational activities that include online labs. On the other hand, a significant proportion of teachers (about 40%) prefer to create their own material rather than reuse some existing ones, while most agreed that it would be useful to create activities with scientists. These conclusions result from the analysis of the data collected during the workshops.

3.3 Suggestions – Concerns in the use of Go-Lab platforms

The majority of teachers emphasised the need for workshops and seminars on how to use the Go-Lab platform. Most agreed that they would prefer to have training before using the platform while some of them insisted on the need to have a good updated user manual or short screencasts showing users how to perform the different tasks. In other cases, attendants expressed the view that follow-up training workshops should be organised before they can use the platform and implement an activity in their classroom. Online tutorials or printed guidelines would be deemed also useful to have.

Participants suggested to include a game-based activity in the overview, which would aim to assess students' knowledge. Some participants stated a preference on a more playful platform, interface and lab appearance. They insisted also that students nowadays prefer a more game-full learning process.

Possible restrains – barriers towards the implementation of the tools, resources and methodologies presented during the visionary workshops:

- Extensive curricula – not enough time
- Lack of ICT tools in school
- Teachers' lack of acquaintance with the use of ICT
- Lack of technical support in school
- Lack of school support – cooperation
- Lack of interest from the students – students' attitude
- Number of students per class

The main organizational barriers include a lack of financial support and the lack of correspondence between curriculum and the use of online labs; further, lack of time by the teachers and lack of training measures may represent significant hurdles in the application of inquiry learning methods at schools. Finally, the lack of general organizational support and communication between stakeholders may negatively influence the implementation process. Identified technical barriers include, on the one hand, problems on the schools' side (e.g. availability of the ICT infrastructure and internet) and, on the other hand, problems on the online lab providers' side (e.g., usability problems, experimental failures, availability of technical support, etc.).

The Go-Lab project can provide support in addressing some of the barriers as identified by the teachers and students at visionary workshops. First of all, there are a number of technical barriers that can be addressed by the project including the usability problems, online lab search and personalization, student management and experimental failures. Also, organizational barriers can be reduced with appropriate training and dissemination activities offered by the project.

However, several barriers remain out of scope of Go-Lab project, as they can be only indirectly addressed by the project activities. These include organizational barriers such as the lack of time and curriculum, insufficient funding, and school support. Although these hurdles can be addressed with project dissemination activities, e.g. by increasing the awareness of political and public bodies about the Go-Lab approach and the need to support its implementation by providing funding or changing curriculum, the project does not have a direct influence on the decision makers. Technical barriers include availability of sufficient infrastructure (computers, internet access, etc.), which also needs support at governmental or at least school direction level.

These restrains – barriers should be considered as challenges to Go-Lab implementation.

Barriers	**Challenges**
Extensive curricula – not enough time	The Go-Lab services help teachers better organize their time and activities. Go-Lab offers different tools in the same place thus helping teachers to gain time.
Lack of ICT tools in school	No special tools or infrastructures are needed since Go-Lab offers easy to use solutions.
Lack of technical support in school	No special technical support is needed since Go-Lab offers easy to use solutions.
Lack of school support – cooperation	Go-Lab builds an international community of use
Lack of interest from the students – students' attitude	Go-Lab offers innovative and easy to use tools that can spark the interest of students.

4. Inputs from Stakeholders' Consultation

In this section, the stakeholders' consultation activities are presented. The description of each method used starts with the clarification of their purpose and presenting then the consensus points and the issues that generate debate.

4.1 Purpose of the consultation

The Go-Lab partnership consulted with various categories of stakeholders through interviews (in particular science education experts, school leads, publishers and policy makers). These interviews reflected the experts' views on:

1. Strengths and weaknesses of the present science education practice
2. Likely evolution
    - Positive trends, affecting science education or education in general
    - Trends producing a negative impact on science education or education at large
    - Necessary actions at policy level to maximize the impact of favorable trends and reduce the impact of undesirable trends
    - Role of industry
3. Teaching and learning practices
    - Ways of teaching and learning to increase quality of science teaching at school
    - Barriers to their large-scale adoption
    - Role of ICT in improving science teaching and learning
4. Specific recommendations
    - Teachers' competences and motivation to change
    - Learners' attitudes to science and motivation to learn
    - Organizational (school level) and institutional (Ministries, regional and local authorities) lines of action that could produce positive impact and remove barriers to change
    - New ways of using ICT for teaching and learning science
    - Use of inquiry-based learning in science education
    - Access to remote laboratories through ICT to make science education more effective and attractive
    - Use of open educational resources
    - Evolution of text books for science education

4.2 Main points of agreement

All the stakeholders that were interviewed agreed on certain common views:

- The importance of (motivated) teachers in science education. In most countries, teachers are not given the respect they are due, they are not adequately facilitated, they are not well paid and they are not offered ongoing training opportunities.
- The importance of up to date content in science education. What is taught in schools is not relevant to the current developments and is not linked to everyday or daily life. Students need to understand why science is important and see what its value is.

- The importance of the adoption of innovative teaching methods in science education. Inquiry based approaches to learning science incorporating students' active investigation and experimentation are necessary to motivate students to learn science.
- The important role of ICT to support innovation in science education.

The current trend in science education demonstrates that concepts and skill are at the ends of its attention. But what science education lacks is the proper background that allows students to understand and use the information and skills that they are taught. As a result, science education is not as attractive for students as it could be, as they do not find great interest in it.

A second point of great interest identified by the stakeholders is the technology and science education inclusion. The developing interest of students in technology can serve as a vehicle for arousing their interest for science education. Using technology for learning in science education students by themselves may discover the bewitchment of the physical phenomena.

Another trend that refers to the policy followed in science education is the involvement of teachers and students as well as outside stakeholders to the plan to improve it. There are great challenges to be met, such as evaluation, the change of instruction and assessment methods and mainly the pass from mimicry to understanding.

Engaging students' minds presupposes a set of reforms, and such engagement happens when students ask questions and wonder to find interesting pursuits. Topics of interest emerge in a way that evoke questions for students, teachers encourage students to put their views and express themselves with different ways, students are encouraged to take actions and create original products based on the understanding of their studying and learning, and overall students have the sense that the results of their work or actions are not predetermined and predictable.

4.3 Synthesis of the debate

The major controversy in teaching of science education refers to the fact that most educators adopt only the traditional model which relies on the textbooks and state curriculum framework. The current school science approach serves the commitment of educators to the limited use of "external" sources of learning in science education. In the framework of school system, students learn basic concepts of science and their use in practice in order to understand and explain the world. But the key point of learning is the relation of these concepts of science with their lives, experiences and concerns, rather than with arbitrary abstractions. Students should be in a position to understand the inter-connections of key ideas of science, which is an approach accepted and desired in parallel by scientists.

The lack of relevance between science and technology appears to be the greatest barrier for "good" learning and continuous interest in the subject. Thus, there is a need for empirical findings and theoretical perspectives that can support the improvement of the curricula and enhancement of the interest for science. A starting point for that is the admission that School science learning should build on situations connected to the lives of the students. The permanent tension that exists is as follows. In the local level, it refers to the matching of the interests of students with their contexts and in a broader level, to encourage students to overcome their immediate environment in order to get a wider view of the world. A safe solution for this tension is students to be facilitated to reflect on what they have learned and go beyond their relevant contexts. Students should learn to search, explain, understand, verify hypotheses and evaluate the outcomes of their investigations. In order the teaching principles above become a reality, a change in the way many teachers work is required.

Adopting the view of Schreiner and Sjøberg (2004) that

"“S&T education for all” should primarily prepare the young people to meet the challenges in their own life and environment. We would also add that adolescence is not just a preparation for later life, but is an important part of life itself! Students at school should therefore experience this period as interesting, joyful and stimulating in itself”.

“we claim that a positive experience in school with science education is more likely to retain or event raise the interest for science alive and motivate lifelong learning in related topics so as to better handle the everyday challenges. Therefore, the use of technology for school level science education may contribute to positive experiences of students inside the classroom with profound effect to their broader personal development. Sources from the internet and on line science museums can be used to serve this need, but should be accompanied by scientific ideas used to explain the everyday phenomena.

The above approach reveals the need for quality resources both for teachers and for students. This is the case in many countries, since educational research is producing material with the financial support of governments in local or inter-European level. This trend on one hand opens up great possibilities for teaching in science education and in parallel creates challenges for science education for teachers, which must prepare the latter to welcome and adopt such approaches and thematics.

5. Synthesis of discussion papers

In the first eight months of the project the WP6 partners were active in the identification of the main challenges and opportunities that the Go-Lab project would encounter in its implementation and long term development.

A collection of six "Challenges and Opportunity Papers" was produced: the first one looks at the international debate on the future of science education and identifies five concrete areas of attention that are then developed by the other Papers.

In this chapter we offer a synthesis of these discussion papers which constitute the core of the Future Challenges Report, while the full Papers are presented in Annex I of this Report.

5.1 The present and the future of science education: what is desirable?

This section presents some of the aspects that would facilitate the modernization of science education practice.

5.1.1 Learners who know how to investigate

It is desirable, for the future, that students develop their capacity to construct their own knowledge and create their own understandings and meanings. The Go Lab project has recognised this since the beginning: from the originl proposal we can quote some paragraphs that express its awareness level and commitment to change:

"Europe needs young people who are skilful in and enthusiastic about science and regard science as their future career field in order to guarantee competiveness and prosperity. To ensure this, large scale initiatives are needed that engage students in interesting and motivating science experiences. Such initiatives should follow an Inquiry-Based Science Education (IBSE) approach to involve teachers as the main stakeholder and to ensure engagement of other stakeholders, e.g. science laboratories".[1]

Motivation and engagement are recognized as the most essential elements of successful education as they can inspire lifelong learning. Since motivation is considered as the protagonist in learning experiences, strategies that serve this end are required.

The following trends should be taken into account in order students acquire a feel of protagonism in learning procedure:[2]

- **Personalization instead of standardization of learning:** According to this approach, the motivations of individuals to learn is increasing when the content and the way of learning is coherent with their personal background (preferences, interests, existing knowledge, learning experiences). Individualization of strategies can be accomplished through ICT that offer innovative content and solutions to individuals to learn at their own pace.
- **Integrating the learning contexts of individuals:** Motivation may be enhanced through the implementation of integrated learning paths, which are formed by the learning experiences of the individual. The key to an identity as a lifelong learner is the continuity in learning, which stimulates further engagement in learning.

[1] Go-Lab Project, Our vision. Available at: http://www.go-lab-project.eu/our-vision

[2] VISIR Project, Valuing learning, motivation, awareness and value of learning. Available at: http://visir-network.eu/vision/valuing-learning/

- **Personalized assessment supporting awareness and motivation in learning:** Assessment in considered as a key enabler or motivation. Nowadays, with the proliferation of technology-enabled stimulations, students tend to learn more and more individually, an issue that creates particular demands for self-management and self-control. In this regard, the assessment may guide the learner towards the "appropriate" formal, non-formal and informal learning experiences, conducted in parallel and in complementarity, so as he will be able to achieve his personal goals. Thus, assessment is transformed from an auditing to a creative and supportive process towards future education.[3]
- **Increasing the intrinsic motivation for science learning:** motivation in general is divided to intrinsic and extrinsic. Schools and teachers typically focus to the raise of extrinsic motivation, whereas the research and practice underline the significance of intrinsic motivation in how students learn, the learning achievements as well as the sustainability of learning (Shumow and Schmidt, 2013).

5.1.2 Teachers who are able to create

Education needs to wake up learners' attention by means of their positive emotional feeling and to encourage student's interest in science and technology: this is the main task for teachers.

Teachers should be creative, motivated and design educational activities to increase the interest of their students for science. It is necessary to promote a dynamic engagement of the learners. The main objective of teachers should be the promotion of learners' independence and autonomy. Literature indicates that autonomy is positively related to perceived competence, enjoyment, decreased anxiety and grade-focused performance in science learning (Black and Deci, 2000). In this way, students can experience a wide repertoire of learning practices and strategies to learn, including those that turn out to be most engaging and motivating for them.[4]

It is important also so to produce a methodology for helping teachers to upgrade their current science teaching practices by using eLearning tools and resources and by designing and presenting inquiry based educational activities in a structured and simple way. Modern ICTs have been proven to enable teachers to engage and motivate students to a greater degree than other means (Betts, 2003).The proposed methodology will also aim to describe ways of improving key competences of teachers like using new technologies in daily practice, organizing learning opportunities for students and dealing with students' heterogeneity. The main science inquiry processes supported by different computer environments that have been identified are the following: "orienting and asking questions; generating hypotheses; planning; investigating; analysing and interpreting; exploring and creating models; evaluating and concluding; communicating; predicting."[5] Such an organisation could help teachers to support the development of partial abilities of the students. Teachers need such tools (with clear educational objectives) that allow them to orchestrate the implementation of an activity based on their students needs. Such tools have to support inquiry and the development of problem solving skills by allowing users to personalize the experience as much as possible by deploying different eLearning tools and developing learning pathways and their own inquiry strategies. In the inquiry scenarios we will also include career orientations. The intention is to show students the excitement and challenge of doing science and this will encourage them to choose science studies in the future. To enhance the aspect further the design of the proposed activities will

[3] VISIR Project, Valuing learning, motivation, awareness and value of learning. Available at: http://visir-network.eu/vision/valuing-learning/

[4] http://www.tlrp.org/pub/documents/TLRP_Schools_Commentary_FINAL.pdf

[5] Psycharis, S. (2013), p. 70.

include interactive career counselling approaches in order to increase awareness of the value of studying science among students by demonstrating potential career opportunities.[6]

The shift of learning approach to individual autonomy, meta-cognition and critical thinking, has changed the role of teachers respectively. Whereas teachers were expected to transmit knowledge to learners, now their role is to facilitate individual and reflective approaches to learning and knowledge. This means that the standardization in teaching needs to be decreased and teachers should have new competences, including their capacity to articulate the teaching process in all phases. Evidence also underlines that when teachers provide basic support to learners so as to increase their autonomy, their competence, and the relatedness of the newly acquired concepts and skills to their environment, the latter develop their self-regulation for learning and their academic performance (Niemiec and Ryan, 2009)

The new orchestrating role of teachers focuses on the definition of personalized learning context, which can fully favor the ICT technologies. The learner centered approaches in education require the ability of teachers to build on and value the existing learning experiences of students and assure the continuum between learning contexts. This means that formal education is being broaden and that leads to the need teachers posses competences that allow them to successfully bridge the gap between formal and informal education. In the case of science education, the above capacity refers to the integration and use of external sources (for example science labs and science museums) in a way that broadens the horizons of learners and gets out of the traditional teaching practices based on the curriculum and textbooks.

5.1.3 Institutions that are flexible enough and prepared for change

Schools need leadership and autonomy to implement major transformations on how teaching is organized, how the relationship with the local context is structured, how school performances are assessed and compared, how collaboration is encouraged.

The "stuckness" that is frequently attributed to school systems is often the result of some gaps of leadership and autonomy within over-centralised systems.

In many cases, teachers undertake initiatives that come beyond conventional practice. These teachers move over and above the official vocabulary-dense textbooks and encourage student inquiry-based thinking and participation. But the most important is that they relate science courses with students' lives and experiences. [7] The initiatives described should be highlighted in order to be recognized as best practices and introduce an innovative culture in schools that is based on system aware practitioners.[8] We have to instill a design based approach of collaborative learning and inquiry between professional practitioners, thus creating a "pull" rather than "push" approach.[9]

5.1.4 Technologies that make learning easier, more pleasant and more effective

Recent developments in technologies have changed learning outside formal education. Specifically, Web 2.0 has moved the methods of learning to a collaborative process of peer learning. Contrarily, formal education is more reluctant to adopt the new methods of learning

[6] Project: Large Scale Experimentation Scenarios to Mainstream eLearning in Science, Mathematics and Technology in Primary and Secondary Schools, 2013 (Acronym: Inspiring Science)
[7] National Science Education Standards: An Overview, p. 18. Available at: http://www.nap.edu/openbook.php?record_id=4962&page=12
[8] Hannon, V. (2007). "Next Practice" in education: a disciplined approach to innovation, p. 9. Available at: http://www.innovationunit.org/sites/default/files/Next%20Practice%20in%20Education.pdf
[9] Project: Large Scale Experimentation Scenarios to Mainstream eLearning in Science, Mathematics and Technology in Primary and Secondary Schools, 2013 (Acronym: Inspiring Science).

and abandon the traditional ones. Even though in schools teachers are the center of the educational process, there are examples proving that the introduction of ICT can support personalized learning process. The use of ICT in educational process can have many advantages like fostering creativity and individual talents of pupils and supporting socialization and education for active citizenship, while they can support the development of transversal competences and metacognition processes.

The ICT devices and services used in an experimental way in education can successfully "support the active learning processes based on contextualization. They can favor metacognition processes and stimulate competence development by requiring an active engagement of the learner"[10]. The ICT can offer access to a variety of sources without being confined by the classroom's context or teachers' activities and approach but there is serious danger of poor quality of resources and the information literacy of learners. Thus there is an imperative need for development of the necessary competences to the students in order they can rightly use them in a variety of contexts and circumstances.

ICT can foster innovation in teaching process but also can help learners develop learner-centered experiences and assure balance between autonomy of the learner and the support in learning needed. From the point of view of the individual, the learning process with the use of ICT can be more autonomous and adaptable to his/her own pace of learning, whereas for the teachers it has the advantage that they are facilitated to better orchestrate complex learning experiences of the learners. The main barrier for introducing ICT in an educational process is considered the resistance of teachers to their adoption due to the lack of available infrastructure and adequate training.

A core point of the ICT driven innovation in the school system is the motivation to learn that it offers. As the individual becomes the center of his/ her life-wide learning experience through the implementation of a learning based on contextualization, what is learned becomes meaningful. In the workplace corresponding advantages are detected, as new learning services help the development of competences in context. Overall, ICT can have serious effect in motivation compared with the traditional forms of learning.[11]

ICT as well can supports the introduction of innovative ways of assessment. It can both evaluate the experience of the individual and it can be coherent with the diverse ways of learning in different life contexts. ICT based instruments (like e-portfolio and learning records) contribute to the collection of objective evidence of learning experiences and at the same time offer reflection upon the learning process and its developments. Furthermore, ICT can support social assessment approaches which can socially recognize informal learning. The advantages ICT instruments offer for integrated assessment with a formative purpose are exploitable by both teachers and individuals.

Last but not least, ICT can offer great opportunities for professional development of teachers in two ways. The first refers to the acquisition of the necessary digital competences and the second to their capacity to participate in communities of practices and exchange among teachers. Teacher further education and continuous training have been transformed because of

---

[10] Observing evolution in learning through 11 domains of change. Which role can ICT play in matching the challenges of the xxi century? VISIR vision report y1. p. 14. Project: Vision, Scenarios, Insights and Recommendations on how ICT may help making lifelong learning a reality for all, 2012 (Acronym: Visir) http://visir-network.eu/wp-content/uploads/2013/01/VISIR_Vision_Report_2012.pdf

[11] Observing evolution in learning through 11 domains of change. Which role can ICT play in matching the challenges of the xxi century? VISIR vision report y1. Project: Vision, Scenarios, Insights and Recommendations on how ICT may help making lifelong learning a reality for all, 2012 (Acronym: Visir) http://visir-network.eu/wp-content/uploads/2013/01/VISIR_Vision_Report_2012.pdf

the effects of ICT and are constantly updated since they are increasingly complemented by networked teaching practices.[12]

5.2 Why a motivation scheme or plan is needed

Although several advancements related to the internet and to communication technologies are now widespread in most European schools, the use of online and virtual labs by teachers and students in their everyday practice is lagging behind due to many factors. One of the main factors or barriers to the introduction and adoption of a change, in some countries with less technologically advanced educational infrastructures, can be identified to be the so-called “inertial reaction” or resistance presented by the educational system as a whole, including policy makers, educational authorities, in-service teachers and students. To cross this barrier the key stakeholders of such a change, in particular the teachers and the students, need to be motivated to do so and also to be further informed and/or educated about the educational benefits of this change. It is not unlikely that even the excellent and most pioneering teachers may lose their interest and passion when they stay unsupported for long in a negative and indifferent environment that may in addition pose further policy and curriculum related obstacles to change and innovation.

Thus a motivation scheme, plan or strategy needs to be constantly implemented in order for a change to be effective, sustained and widespread. Motivation of teachers and students can be practically interpreted into tangible and intangible rewards to not only acknowledge the effort invested and the time spent but also to appraise their excellence and intellectual value. In the following we propose and discuss how to motivate teachers and students to use online, remote and virtual labs and accomplish partial or even radical change in their traditional school practice.

The proposed ideas discussed below may not be possible to be implemented at once and as a whole within a given educational system. However a step-by-step or staged approach can always be feasible and effective to create an initial critical mass of change agents who will further compose the core of incubation and develop into a self-sustained cluster of excellence and best practices and a community susceptible to further innovations.

5.2.1 How to motivate teachers to use online labs

As already mentioned, teachers are the main key stakeholders in any educational system and their everyday task is very challenging and very demanding in all respects. Furthermore, and in particular science teachers feel the pressure that is coming from their students and society that they should be competent in keeping up with, be able to understand, explain and communicate the technological advancements that are taking place in everyday life and the basis of which are the science subjects they teach.

On the other hand, although the demand for innovation is intrinsically set, some teachers, and in some cases the educational system as a whole, choose to ignore it and resist change in order to avoid “leaving their comfort zone”, i.e. change the way they are used to teach, practice and assess. Others do not feel confident enough or adequately motivated to adopt a change in their conventional thinking and practice. These teachers with proper motivation and appraisal, complemented by well-designed opportunities for professional development, are likely to invest effort and time that may be needed in order to use online labs in their regular classroom

[12] Observing evolution in learning through 11 domains of change. Which role can ICT play in matching the challenges of the xxi century? VISIR vision report y1. Project: Vision, Scenarios, Insights and Recommendations on how ICT may help making lifelong learning a reality for all, 2012 (Acronym: Visir) http://visir-network.eu/wp-content/uploads/2013/01/VISIR_Vision_Report_2012.pdf

practice. In parallel, there are no available policies or regional guidelines enhancing the extrinsic motivation of teachers to adopt online labs in their teaching practice, exploiting the potential of contemporary technologies so as to create authentic learning experiences for their students.

Below are listed and discussed various ideas and concepts that may develop into a concrete motivation scheme within the official educational system or become a part of a motivation strategy endorsed by lower or higher level educational authorities, such as school principals and directors, school counsellors, policy change managers and consultants. The list is in random order and does not imply order of significance, priority or effectiveness.

Quantify educational benefits

The majority of science teachers have gone through a demanding mathematical curriculum during their university studies, therefore they possess a strong mathematical background. As a consequence when they are confronted with quantifiable arguments they have the capacity to comprehend and appreciate their significance. In other words, it is recommended that seminars and Go-Lab workshops include, show or refer to studies that document in a quantitative way (i.e. with graphs, survey statistics, trend lines etc.) the educational benefits to students and learners, in terms of the effectiveness and improvement of conceptual understanding when they use online labs. This will not only convince but also motivate teachers to at least learn about and try to adopt them simply because they will be proven useful in their work.

Learn from experts – follow the experts

Most people tend to be followers and like to learn from, meet and discuss with experts and best practitioners. In this regard, regularly organized seminars, workshops and dedicated winter or summer schools organized by or in collaboration with educational authorities, professional unions/associations or science organizations and institutions are great opportunities where experts and innovative teachers can present activities they have developed using online labs of various complexity, target age of students, science subject etc. that can spark the interest of traditional teachers. During these events informal discussions and brainstorming between teachers and experts can further inspire and kick-start their creative thinking on how online labs can be incorporated in teaching. Also these interactions when held in parallel with hands-on workshops, tutoring and other support activities can lower the confidence threshold of less experienced teachers. Overall, the collaboration of teachers with other stakeholders, operating outside the typical school borders, may “open schools” and formal learning to the community, enabling an “osmosis” approach that facilitates the so called “situated learning” as well as the relatedness of science teaching with the society and the environment,

Offer intangible rewards

All people like to be rewarded in recognition of their value, devotion, talent, expertise etc. In this regard, an acknowledgement of their accomplishments by peers, co-teachers, educational authorities, professional unions, associations and societies at local, national or even international level may be considered as serious extrinsic motivations. In practice, this may be facilitated by the organization of educational contests for teachers and students that promote the use of online labs in the classroom. An example of such a contest could be the development of educational scenarios or activities using online labs under a broader science theme or a more specific one (e.g. in connection with celebrations of a key event such as a scientific discovery or the birth of a renowned scientist). The teachers who design and implement the best activities will be awarded with a prize, such as a diploma or certificate.

Offer tangible rewards

Further enhanced possibility to the aforementioned is the case when a winning award or official acknowledgement can be accompanied by a tangible reward such as a scholarship, a funding support to participate in a conference or school for professional development, a monetary or material prize such as equipment, free of charge membership or subscription to science magazines etc.

Advances in professional development

A series of seminars related to the use of online labs can be organized by or in collaboration with the local or national educational authorities as part of an accredited scheme of professional development for in-service teachers or teachers-to-be science students. In this way teachers will be motivated to participate not only in order to enhance their teaching skills and practice the use of online labs but also to acquire credit points that contribute to advancement in salary scale and professional status. Thus, this effort could be linked with a broader teacher evaluation scheme that takes into account the adoption of innovation in their daily practice.

5.2.2 How to motivate learners to use online labs

The use of online labs aims at supporting inquiry learning by providing students, and in general learners, the possibility to conduct scientific experiments in a virtual environment and/or remotely operate scientific apparatus which would be inaccessible otherwise due to limitations such as distance, cost, weather conditions, safety regulations etc. Therefore in this way students develop knowledge on both the content of science and also on how science advances and how scientific research is conducted. Although this approach may sound tempting, attractive and challenging it still needs to be complemented by certain motivation actions in order to become a successful common practice of students and learners.

Below are listed and discussed some guidelines to science teachers and educators on how to motivate their students in using online labs. The list is in random order and does not imply order of significance, priority or effectiveness.

Provide links to everyday life

Science curriculum and teaching are often criticized for being unrelated to everyday life and experience and thus for becoming boring and not interesting subjects of study. The advancements in fundamental sciences form the basis of the present technological civilization and are key ingredients to the future prosperity. However, merely to state this fact is usually not effective and sounds unfounded to students, soon-to-become active citizens, and to the majority of the society, even in technologically very advanced countries. By using online labs in science teaching, that offer a plethora of simulations and interactive experimentations explaining phenomena and concepts on which numerous practical applications are based provide a link to everyday life science and technology that motivates and engages students.

Expect and praise excellence of high achievers but also provide extra support and guidance to low achievers

Talent, inclination, consistent track record of achievements in using online labs in science learning should be appraised by teachers in order to keep increased the learners' interest, the enthusiasm and the motivation. Low achievers should also receive extra support and guidance when needed in order to minimize as early as possible gaps of knowledge and the development of misconceptions that could further lead to scientific and technological illiteracy. Furthermore assessment of outcome and student's progress should be not only in terms of final results but also in terms of effort, ingenuity of approach and out of the ordinary creative thinking in problem solving.

Offer opportunities of intangible or tangible rewards

Teachers should seek for and take any opportunity, such as science contests, fairs or exhibitions that offer intangible or tangible rewards to the winning participant students. Such events are usually initiated by local or national educational authorities, universities or science research institutions, science and technology museums etc. and the use of online labs can be a key component of the submitted proposal or subject of candidate's project. Individual or team participation is strongly encouraged, it nurtures the enthusiasm, interest and creativity of students and is likely to lead to deep memorable learning experiences. In addition students working in a team or individually develop crucial social and technical skills such as communication and presentation skills, negotiation, reasoning and argumentation competencies, project management, prioritization and scheduling capacities etc.

Assign project work in using online labs

One of the key advantages in using online labs in science teaching and learning is that their use is not limited by the classroom hours and equipment, enabling the bridging between formal and informal learning. Teachers by assigning project homework can extend student's learning time and enhance their experience and conceptual understanding. Furthermore the use of online labs at home, often resembling a game setting, may engage students' parents thus leading to an enjoyable learning process for the family.

Give control to students

Children of all ages and backgrounds love to seriously resume and undertake adult roles and responsibilities when given the opportunity. So, further to the above mentioned suggestions that motivate students, i.e. participation in contests and assignment of projects, and in close relation to those, teachers are advised to occasionally give control of the teaching and learning procedure to students and guide them into collaborative and group work on a selection of science subjects using online labs that they will work on and prepare to teach them to their fellow students. Again in this case as already mentioned, students not only develop scientific knowledge and understanding but also by resuming roles and responsibilities they develop and practice key social and technical skills that they will accompany them in the future irrespectively of the career paths they'll choose to follow.

5.3 How to adapt pedagogical practices

Some of the most urgent questions requiring an answer in the world of education relate to the fact that education is often unappealing to young people and to the difficulties many students have in learning. Many students find it difficult to finish their education, some get through it only after having experienced disappointment and demotivation and others eventually give up altogether and drop out of school.

These are crucial questions that all those who work in the field of education - at different levels and with various qualifications- have to deal with.

Motivation is a crucial element in teaching-learning processes: not only for the pure act of learning, but specially because generates or feeds our ability to learn. Therefore, as this has a very positive role in the performance, the teacher should have it in mind in the design of the didactic strategies and methodology and in curriculum implementation.

Academic activities always have more than one meaning, as they contribute to the achievement of different goals. However, not all goals are equally important for each student. This varies in importance depending on their personal orientation and the different situations they encounter on it throughout their educational itinerary. Therefore, taking into account that different targets often have opposite effects on the results of the learning experience, it seems important to know which those effects are, in order to know how to help foster the motivation of your students.

The basic meaning that should surround the act of learning is that, by itself it increases the capacities and competences of the learners, making them more competent, and by doing so enjoying it. When this happens we say that the student works intrinsically motivated, being able to stay absorbed in his work, overcoming boredom and anxiety, looking for help and information spontaneously if really needed to solve the problems encountered, reaching to the point self-regulating their learning process. So, the question at this point is: how as a teacher can I help my students getting to this position of intrinsic motivation? There are some elements that play a key role on that purpose, amongst them:

- Try to make the *learning experience functional* to the student: to learn something useful. It is fundamental that we are able of making aware our students about why it is important and useful, in short and long term, what we propose them to learn
- Try to use the learning experience as a tool to increase the self-esteem, the self-efficacy, the behavioral control and empowerment of the student
- Base your methodologies on various and diversified learning approaches rather than memory and repetitive activities and methods
- Collaborate with the students in the planning of the learning process and try not to make them feel the imposition of it
- Establish personal relationship with the students deeper than the teacher-learner one – become their mentor
- Make them aware of the fact that learning is a process that does not finish in a certain moment and place, and so it not a goal or a finality in itself
- Make them co-responsible of their learning experiences
- Provide them feedback based on their assessment

5.3.1 Understanding of the lifelong learning continuum

As the European Council Resolution stated[13] "*lifelong learning must cover learning from the pre-school age to that of post-retirement, including the entire spectrum of formal, non-formal and informal learning. Furthermore, lifelong learning should be understood as all learning activity undertaken throughout life, with the aim of improving knowledge, skills and competences within a personal, civic social and/or employment-related perspective. Finally the principles in this context should be: the individual as the subject of learning highlighting the importance of an authentic equality of opportunities and quality in learning*".

In principle it is accepted that formal learning is assured for its quality whereas non-formal and informal learning are not, since they are not controllable and less structured. On the other hand, formal educational system, which is under state control, is too structured and rigid that it is not able to support active life-long learning of individuals.[14] And in this regard the EU has already

[13] Official Journal of the European Communities "Council Resolution" of 27 June 2002 on Lifelong Learning (2002/c 163/01).

[14] SEEQUEL (2004). Sustainable Environment for the Evaluation of Quality in E-Learning. Quality guide to the non-formal and Informal learning processes. Available at: http://www.menon.org/wp-content/uploads/2012/11/SEEQUEL-TQM-Guide-for-informal-learning.pdf

initiated action towards the recognition of non-formal and informal learning, especially in the field of youth[15].

This does not mean that there are no examples of learning experiences in all three formats. All formats (formal, informal, non-formal) of learning experiences can have both positive and negative experiences for individuals, as they depend on variables that are not predefined. The methods of quality assurance of formal learning and teaching experiences are connected to the policy agenda at European Level while the efforts for development of quality assurance tools for non-formal and informal learning and teaching are not of corresponding strength.

The three learning formats are characterized by different elements and one format can share the same aspects with the others. This means that the definition of each one is more a matter of classification rather than a matter of real assessment of the learning experiences as each learning format of the three shares common features and characteristics with the others. The mail point of interest is how these formats can be integrated in order to provide a holistic strategy for individual, organizational and societal development. The key issue is the communication and the correlation of each learning format with the others and the integration of informal and non-formal learning in the formal one.[16] In the field of science education, the capacity to connect learning that cannot take place out of school, in a variety of situations, with formal learning, is a key competence to be developed by teachers and learners.

5.3.2 Understanding of the importance of planning

It seems a truism, but it should be clear that planning is a fundamental moment of science learning process. We cannot imagine that an engineer or an architect to build a project without a detailed plan of action, just as, when we want to generate significant knowledge students should be organized clearly in all steps to ensure success.

Teaching often gives unpredictable results. Often the minds of students, some external event or any news should encourage the reformulation of everyday practice. In order to have the flexibility necessary, it is required that the action plan is clear, flexible and proactive.

Many times we have seen the process and planning tools only as a requirement by the authorities, but the idea is that teachers internalize that this resource will help organizing their work and save time.

In addition, instructional planning to reflect and make timely decisions, offers a guide about what are the needs of students, how to organize methodological strategies, interrogates if plans and processes of learning should be acquired by all and to which extent, and thus gives attention to the diversity of students.

Another important aspect of planning is the preparation of a didactic learning environment that allows teachers to design experiences where student interactions arise spontaneously and collaborative learning can be optimal. It also states that good planning:

- Avoids improvisation and reduces uncertainty (so teachers and students know what to expect from each class) allowing in parallel some degrees of freedom for creativity;
- Unifies criteria for greater coherence in the efforts of teaching within institutions;
- Ensures efficient use of time;

[15] http://europa.eu/legislation_summaries/education_training_youth/lifelong_learning/c11096_en.htm

[16] SEEQUEL (2004). Sustainable Environment for the Evaluation of Quality in E-Learning. Quality guide to the non-formal and Informal learning processes, p. 22. Available at: http://www.menon.org/wp-content/uploads/2012/11/SEEQUEL-TQM-Guide-for-informal-learning.pdf

- Coordinates the participation of all stakeholders in the educational process;
- Combines different teaching strategies focused on the daily practice (group activities, case teaching, problem-based learning, debates, projects) for students to make connections that give meaning to their learning.

Planning should begin with a reflection on what the capabilities and limitations of the students, their experiences, interests and needs, the subject being treated and its logical structure (selecting, sequencing and rank), resources, what is the purpose of the issue and how it will be addressed.

Successful planning has to be flexible and adapt to permanent changes as the situation demands. To check if the schedule is met, must constantly monitor, verify, rethink and adjust all elements, with the aim that students achieve mastery of skills with different performance criteria. The teacher should therefore be open to make adjustments, in order to further planning.

The use of a variety of assessment and evaluation techniques is considered more than desirable. Its selection depends upon the aim of the assessment, the curriculum objectives and the learning styles students adopt. Below are identified crucial elements during the assessment of the planning process:

- Students should be aware of the evaluation plans, criteria, objectives and procedures and in some cases they should express their opinion on the assessment criteria.
- Assessment and evaluation techniques and tools should take into account in a sensitive way the student, school, family and community situations and the cultural and gender specifications.
- The assessment and evaluation should favour students and encourage them to actively participate in the relevant procedures, in order to be benefited through transferring knowledge and capacities to their life.
- Outcomes and data of the assessment and evaluation should be become acquainted to students and parents in order to be exploited in the right way.
- The planning of the evaluation should be based on the data of the assessment. The comparison of assessment and evaluation information to curriculum objectives gives teachers the opportunity to decide upon the enhancement of the instructional requirements.

Through making explicit the planning what we intend to carry out in the science learning activity, although we work in a high quality way and although we intend to cover all aspects, many times this work hardly reflects the plurality of the learning situations at play. It is impossible to "control", or even just to take into account, all the variables that come into play in a pedagogical practice. What happens in the classroom or during the activity is always more complex and unpredictable than what we can plan.

In other words, planning is a reference but does not give all the answers. The complexity and unpredictability of educational practices requires the ability to adapt to different circumstances and be prepared to change if necessary. Accordingly, the process of planning is never fully cut and dried. The everyday reality often imposes rethinking and re-orientating the proposed plan. Therefore, flexibility is necessary first of all when planning.

The planning and design means reflecting on what to teach, why, how, by what, when, etc. That is, explicit content, objectives, teaching strategies, learning activities, resources, evaluation forms.

Each of these components makes sense for their involvement and relationship with others so that leads to an objective, an activity or resource that requires specific teaching strategy and it is possible to develop such content, etc.. So, planning is an integrated system, an organized one whose parts or elements are interrelated and consistent.

5.4 Identifying barriers for implementation of inquiry learning at school

Several kinds of barriers have been identified stopping teachers from making use of digital learning activities and online labs in particular in their classroom activities. Below, the most common are presented.

5.4.1 Literature Review

The implementation of inquiry learning at schools is a relatively new initiative, which explains the lack of scientific literature devoted to this topic. However, some resources describing challenges in ICT and online learning implementation in schools could be found.

Categorisations of barriers

The authors suggest several categorisations of barriers for the use of ICT and particularly educational technology in schools.

1. Extrinsic vs. intrinsic barriers

Several studies divide implementation barriers in two categories: extrinsic and intrinsic. However, the mean of these categories can be different. Hendren (2000) relates extrinsic barriers to organisation, whereas intrinsic barriers are connected with individuals, e.g. administrators and teachers. Ertmer (1999) referred to extrinsic barriers time, support, resources and training that are needed, and to intrinsic barriers the attitudes, practices, beliefs, and resistance of involved stakeholders. (Bingimlas, 2009)

2. Material vs. non-material barriers

Pelgrum (2001) refers to material factors e.g. insufficient number of computers, software copies, and other equipment at schools. Non-material factors include lack of ICT competency by the teachers, difficulty of integration of educational technology in instruction, as well as lack of teacher time (Bingimlas, 2009).

3. Micro, meso, and macro level barriers

According to Balanskat et al. (2006), micro level barriers include factors related to teachers' attitudes and ICT approaches, meso level barriers refer to the institutional context, whereas macro level barriers relate to the wider educational framework. Similarly, Becta (2004) grouped barriers in individual (teacher-level) and institutional (school-level) barriers.

This paper examines institutional barriers and divides them in organisational (e.g. availability of suitable infrastructure, organisational support from school administration, efficient teacher training) and technical barriers (e.g. broadband speed). Individual barriers, such as attitudes, motivation, and resistance to change remain out of scope of this document.

Organisational barriers

Organisational barriers can be generally divided in five groups:

1. Lack of resources

These barriers include availability of the hardware (computers, headsets, etc.) and software needed to introduce online learning. Even if there are enough PCs to be used in class, high maintenance and update efforts might be required; moreover, technical infrastructure must be available for teachers and students also out of class to prepare to the lessons; technical support during and after the classes is also indispensable. Further, teachers need to be trained to be able to use the software in its full range of functionalities.

If talking about the introduction of inquiry learning, new personnel roles might need to be established: e.g. system administrator taking care about the equipment and/or inquiry learning facilitator instructing teachers and assisting them in creating new learning programs, scheduling online lab sessions and taking care about general organisation (Bingimlas, 2009; Gahala, 2001; Bakia et al., 2011). Each of these factors can represent significant additional costs for a school.

2. Lack of effective training for teachers

There are often not enough professional development measures provided for teachers and allowing them to learn new teaching methods and practices as well as to gain hands-on experience with the used software. Also, provided training activities not always consider already available knowledge and experience, and do not differentiate between multiple skill levels (e.g. in the ICT use). But more importantly, it is hard to plan time for training without distracting teachers from their duties at school (Gahala, 2001). Finding balance between current duties and new initiatives might represent a barrier in involving teachers in inquiry learning programs.

3. Lack of effective goals in ICT use

The use of educational technology can provide meaningful and engaging learning experience for the students. However, teachers mostly use ICT to prepare their classes, but not during the lessons. Only a few teachers use learning or other software during the class, as exemplified in the GoLab deliverable G3.1. This can be explained not only by lack of ICT competence or confidence to use it by the teachers, but more by missing connection between school program and activities supported with the new tools.

To insure successful use of desktop and online learning tools, schools need to ensure that the technology supports educational goals of the students. A clear set of goals, expectations, and criteria has to be developed based on national and state educational standards (Gahala, 2001). In conjunction with the ICT use, new learning tools have to be developed considering time scheduled for theoretical and practical parts of the lessons. Also teachers will need more time to prepare new scenarios and demonstrations.

4. Lack of time by the teachers

In order to successfully implement educational technologies and, in particular, inquiry learning activities at schools, significant time efforts are needed. Firstly, teachers have to be trained in using ICT in general (e.g., some of them might need training in using web-based tools to support learning and teaching activities or in creating appealing presentations and demonstrations with Power Point), but also in using the Go-Lab Portal and the online labs. Secondly, additional time to create new teaching scenarios and to integrate the use of online labs in classroom activities has to be planned. Finally, the time effort to organize online lab sessions and to prepare the demonstrations has to be taken into account (Bingimlas, 2009; Gahala, 2001; Joseph, 2013).

5. Communication and motivation

In order to successfully implement new educational technologies at schools, communication and collaboration between several target groups has to be assured (Bakia et al., 2011). It is not only a school principal or a teacher taking decision on using innovative tools in classroom. Firstly, government bodies (e.g. ministries of education) have to accept the need for new learning methods, adopt learning programs, communicate this with schools, and provide funding to buy equipment, train teachers, and probably finance additional teaching hours needed for practical exercises of students. Secondly, planned changes have to be communicated with teachers; they should be motivated to extend their teaching methods and to use technology tools during the lessons. Thirdly, the need for new technologies has to be explained to parents in order to minimize resistance from their side; also, parents will probably need to buy a PC, a notebook or a tablet for home use in order to support students to better prepare for their lessons. Finally, students have to be motivated to use new tools (e.g. with assessment for completing practical parts of the courses) and in this regard these tools should be user friendly, joyful and engaging.

5.4.2 Technical barriers

Technical barriers arise mostly from the side of the learning resource or online lab providers. The two main problems here are: (1) accessibility of the resources, e.g. time-scheduling for the use of labs and maximum number of participants in one session (but also in many parallel sessions); (2) technical support has to be provided 24/7, as the online labs will be used by students from all over the world. Further, the data storage might represent a barrier: on the one hand, huge capacity servers might be needed to store the data from all sessions; on the other hand, the users do not always trust the data storage in the cloud. A possible solution would be to provide an export functionality and a possibility to save data on a local hard drive (Schanda et al., 2012).

At schools, technical barriers relate mostly to the availability of appropriate hardware and software (see above), and also to the broadband speed, which might be too low to use applications containing videos, graphics, and other multimedia content. Thus, available technical barriers are closely connected to organizational barriers, such as lack of financial resources or funding as well as lack of efficient rules in the ICT use to support classroom activities of the students.

The next section specifies organisational and technical implementation barriers relevant for the Go-Lab project, which were identified in scope of the Visionary Workshops and summarised in the VW reports.

5.4.3 Visionary Workshops: identified barriers

Data collection

Go-Lab project partners have organized a series of visionary workshops in several countries across Europe to elicit data about the organizational and technical barriers at the respective locations from project stakeholders. The participants were mostly teachers, and some students, who expressed their opinion in discussions and surveys. The results were reported by a set of visionary workshop reports summarized in this document and in WP3 deliverables.

There were several categories of organizational and technical barriers that may detract users from the use of online labs. First are described those problems that were mentioned repeatedly, followed by specific problems.

Frequently stated problems

The category of barriers that was most often discussed by the workshop participants consisted of the usability problems of the existing online labs and Go-Lab mock-ups interface. The comments pointed to the rather complex interface of the lab and the difficult terminology for particular target group of students. Besides the format of the lab, the participants reviewed the content and tools presented in labs and they found some information or tools missing or, on the other hand, difficulties to understand or even being not so attractive. Finally some comments regarding user interface usability pointed out that most labs are available only in English language, which can limit the use in other European countries.

The second largest category of barriers declared by the participants included requests for training. They would prefer to have some form of training due to insufficient familiarity with the labs or lack of acquaintance with ICT.

Time has often been cited by teachers as an obstacle for online labs use in education. This problem is closely related to curriculum. It currently does not provide optimal conditions to accommodate the use of labs and the teachers felt there is not enough time to include the labs in their class.

It was followed by technical problems including the access to ICT and Internet, which was one of the technical problems repeatedly mentioned by the teachers reporting difficulties mainly focused to the reliability and low bandwidth of the connection at schools. ICT access can limit the number of students simultaneously accessing an online lab activity and thus constrain the frequent use of online labs. In addition to the technical difficulties with ICT or Internet access some teachers reported technical failures while carrying out an experiment. Closely related to the technical barriers are financial limitations that were also repeatedly mentioned by the teachers.

The level of novelty of online labs has been indicated by the fact that the majority of teachers have never used a remote laboratory before, although they may have a general awareness about what it is. A problem also repeatedly stated by the teachers was the difficulty to locate such laboratories on the web. When asked about the possible use of the labs, the teachers appreciate the existing ready-made solutions, but most would prefer having the possibility to modify the activities according to their needs for teaching complex phenomena.

Infrequent problems

Several problems were mentioned by individual teachers. The first is the matter of student management, where a teacher expressed the wish to manage the students using an online lab, but with appropriate monitoring of students' progress or another teacher indicated preference of the organization of the student work in the classroom that should be supported by online labs. The second issue was the school support. Although most schools allow their teachers to use online labs and in some exceptions support it, the teachers have reported that they would prefer more support and encouragement for this activity.

5.5 Why we need to raise digital competences of teachers and students

School education is the main issue to improve for our future opportunities, as European citizens, workers, parents, and learners. School experience affects our education level, our personal development, our place in society, and our place in the world of work. In a sentence, school education could and should be the first and most important place where European citizens are forged and should therefore be at the centre of the Europeans' concern and attention.

At the same time, school systems in Europe face a number of common challenges – from Finland to Greece, from Portugal to Romania, that can be summarised in the difficulty to "adapt to the change processes" that are affecting European society. The Communication from the EC to the EU Parliament "Improving competences for the 21st Century: An Agenda for European Cooperation on Schools"[17], summarizes the problem in a precise way: *"Schools must be able to adapt continuously to their changing environment, and the changing needs of students, staff and parents, their key partners."* European school education is in fact often portrayed in public debate as a "slow adaptor" to the change that occurs in society and, in spite of several reforms

[17] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0425:FIN:EN:PDF

processes at national level and mostly converging suggestions on "how to change", a recognised "implementation gap" prevents to call most of the reforms a full success.

A few projects (such as HELIOS from the Lifelong Learning Programme and Kaleidoscope from FP7, or the "Partners in Learning" program of Microsoft[18]) and recent studies (such as "Learning from Extremes" from Cisco[19]) suggest that a wider range of innovation models should be looked at, and that quality assurance could play a pivotal role in school development.

Supporting European school systems in their capacity to change and to prepare better citizens and workers of tomorrow is not only required but it is urgent, as stated in the Learnovation Vision Paper on School Education[20] (p.9). This urgency is even more pressing if we look outside Europe: the 2010 PISA results on students achievements, testing around half a million high school students from over 70 countries, identify a few top scoring countries and regions: Shanghai, Korea, Hong Kong, Singapore, Finland, Canada, Japan and New Zealand. This means that European schools are not doing particularly well in equipping students with key skills - including literacy and transversal competencies – that are needed to succeed in the globalised world as much as other countries are doing. In other words, the current school system is no longer 'fit for purpose'. It is based on an outmoded 'industrial' model that has its roots in the 19th century, and which works in a reproductive rather than transformative mode: as it stands, the school system is more suited to the 'factory' mode of production rather than the current political economy, with its emphasis on adaptability, innovation, creativity and 'flexicurity'.

A specific discourse has to be made about ICT. A 2012 OECD (Organisation for Economic Co-operation and Development) Study[21] (p.144) has pointed to the fact that, in relation to the impact of the wider adoption of the ICTs as communication and content sharing tools in the modern societies (of the 21st century), the out-of-school context (family, social, etc. background) has an increasing impact on the learning achievements, especially when we take into account the building of the key competencies, as the "21st century skills" (or better "literacies"), as the primary learning objectives to be reached. This important observation further justifies the need to approach and effectively embed the use of the ICT in the school environment, not at all from the perspective of how they are or could be used for enhancing the capacity of the "traditional" teaching-centric learning paradigm, but from an holistic perspective of how we are facilitating a systemic change of the way that school learning is taking place. At the end of the day, the way we are enhancing the capacity of school systems, meaning of the teachers, as professionals, and of the schools, as learning organizations, to embed systemic quality as well as innovate in a sustainable way, in order to address the emerging challenges and learning needs of the 21st century globalised societies.

The discussion on the evolution of school education should concentrate on four elements, reported as "engines of change".

- School education achievements should be driven from lifelong learning competences, which should be the center of attention.
- The use of ICT should be expanded in the school settings with the aim to benefit learning processes and contribute to the integration of the informal learning.

[18] http://www.microsoft.com/education/en-au/partners-in-learning/Pages/index.aspx
[19] http://www.cisco.com/web/about/citizenship/socio-economic/docs/LearningfromExtremes_WhitePaper.pdf
[20] http://learnovation.files.wordpress.com/2010/10/learnovation-vision-paper-1-school-education.pdf
[21] http://www.oecd.org/edu/school/50293148.pdf

- Creativity and innovation skills and competences should be an integral element of European education, since it is precondition of the economic and social development.
- School education should give special attention to the acquisition of inter-cultural skills, which are the required for future citizens, workers and entrepreneurs.[22]

5.5.1 Digital Competences in schools – the situation today

A decade ago, the OECD analyzed in its 2001 report “Learning to Change: ICT in Schools”: “Not only do schools have to change in order to accommodate ICT: the very process of learning has to change”. This statement has not lost its validity ever since. Many initiatives were conducted to bring ICT to schools with targets such as e.g. to increase the ratio of computers per school children. In the 2004 OECD survey of upper secondary learning[23], it was found that “Major investment outlays over 20 years have brought modern ICT in nearly all schools in the most advanced OECD countries, but the extend to which computers are in day-to-day use in these schools remains disappointing”. Whereas distribution of ICT devices to schools has steadily progressing, the actual integration in day-to-day school education has always lacked behind – a situation that has not changed until today.

This has led to another effect: the divergence of the growing pervasiveness of ICT in other life sectors such as tertiary education, home and work in comparison to school education. In 2006, a JRC report for the European Commission’s DG EAC[24] reported already a significant divergence in the rate of integrating ICT into learning between the faster moving tertiary education sector and the sector of primary and secondary schools. A further effect has been the consequence: the competencies to benefit from ICT for school aged children are increasingly acquired outside school – e.g. via informal learning from parents and peer- or self-driven learning.

In the same year 2006, the OECD PISA study[25] reported this as a new emerging kind of digital divide among school pupils beyond the issue of access to technology: the one existing between those who have the right competencies to benefit from ICT (Information and Communication Technologies) use and those who do not. This is despite the fact that the need for technical competences to use ICT is declining. In fact, modern ICT is increasingly lowering user entrance hurdles – with already pre school children being capable to navigate smart devices as the Apple iPad. What is however growing dramatically in importance are competencies to benefit from ICT. This means to apply ICT clever and efficient to communicate, collaborate, socially network, search and find, judge information for quality, work across nationalities, protect ones privacy, self-reflect and much more – and ultimately to apply ICT to the problems we would like to solve and the learning challenges we would like to explore.

It has been proved that the use of ICT in learning brings significant changes to the teaching and the role of the teacher, who needs to successfully incorporate new methods in order to meet with the new situation. Good practices are required to set new school learning innovations and also a policy making that achieves balance with top-down planning, creation and sharing of knowledge and the acquisition of the competences needed in learning communities.

---

[22] ESHA (2014). Resistance 2 change. Esha Magazine May/June 2014. Available at: http://www.esha.org/sites/default/files/eshamagazinedownloads/Esha%20Magazine%20June%202014.pdf
[23] http://www.oecd.org/edu/skills-beyond-school/27446844.pdf
[24] http://ftp.jrc.es/EURdoc/JRC47246.TN.pdf
[25] http://www.oecd.org/pisa/pisaproducts/42025182.pdf

Review of the ICT learning policies in European countries has revealed that those with a rather decentralized school system, whereby there are great levels of autonomy, show better performance in this field.[26]

5.5.2 Competences required

In order to identify the roadmap that will lead to the development of digital competences of teachers and students, we need to define the main aspects to be acquired before moving to a desired future.

Our main focus will be on the different areas of the digital competence (Ferrari, 2012):

- Information management

  Refers to the knowledge and skills needed to identify and organize information.
- Collaboration

  Refers to the knowledge and skills of participating in networks and online communities.
- Communication and sharing

  Refers to the knowledge and skills of communicating through online tools.
- Creation of content & knowledge

  Refers to the expression of creativity and the construction of new knowledge through technology and media.
- Ethics & Responsibility

  Refers to the capacity of behaving in an responsible and ethical way.
- Evaluation & Problem solving

  Is the identification of the right technology and/ or media to solve the identified problem or to complete a task.
- Technical operations

  Refers to the knowledge and skills for correct, efficient and safe use of technology and media.

ICT does not include only the use of computers and the internet but everything that teachers and students can use in teaching and learning settings. Innovation exists when a teacher employs resources and methods that have not been used before. This means that the employment of technical resources does not automatically entail innovative practice; it can only support innovation. The most representative phrase is the following "Innovative pedagogical practice that makes use of ICT is not the same thing as using ICT in education" (Körös-Mikis, 2009). In many cases the technical resources may not even be present. "For instance, the school may not have a computer network, but teachers might have access to such networks outside of the school, enabling them to engage in sharing experience and, locate more up-to-date teaching materials, thus raising the quality of education - so in the course of pedagogical practice education is embellished by the following:

- the opportunity to handle and publish data and information
- easier accessibility and storage of large volumes of data
- rapid and inexpensive transfer of information".

[26] Kastis, N. (2007). Observing the e-Learning phenomenon: The case of school education. Analysing the transformative innovation of e-Learning. eLearning Papers, No 4, May 2007, ISSN 1887-1542.

5.5.3 Why we need to increase the effectiveness of the use of education resources

In order to approach our subject, we need first to define education resources. Education resources can include a wide range of materials offered freely and openly for educators, students and self-learners to use and reuse for teaching, learning and research. According to OECD (2012), *Preparing teachers and developing school leaders for the 21st century: Lessons from Around the World,*[27] the resources are not limited to content but compromise three areas: learning content, tools and implementation resources. For instance, a tool can be a piece of software which supports the development, use, reuse and delivery of learning content, content development tool, games, etc. Education resources can be considered open source resources and materials that can be adapted to meet the needs of teaching and learning. OERs are available and shareable both in digital and printable formats, so the definition should expanded.

But why do we need to improve the effectiveness in the way we use education resources? One reason for increasing the use of education resources is the radical increase in the use of online learning environments. On line learning environments can promote student – content interaction in a better way by providing students with feedback on their performance. While online learning environments have their own rules and ways of interaction with the students, education resources remain at the core of their action. In this context, the effective use of resources has a critical role in facilitating knowledge exchange, overcoming distance barriers and finally providing a sustainable alternative to the traditional classroom.

Moreover, the effective use of education resources can contribute to the development and provision of learning opportunities to a wider, less privileged audience which faces social and physical restrictions. In these difficult times of economic recession, the efficient use of education resources provides the opportunity to experience and access information and knowledge to those students, teachers, schools that otherwise would have been impossible to gain.

The increase of educational offer through the access to education resources have an impact on the completion of upper secondary qualifications.[28] According to a communication titled *"Tackling early school leaving: A key contribution to the Europe 2020 Agenda"*[29] sent to the European Parliament and European Council by the European Commission in the 30th of November 2011: "*Today, some six million young people drop out of school each year – about 14% of all pupils. They are more likely to end up unemployed, poor or otherwise marginalized"*. The efficient use of education resources can intrigue interest and curiosity, show potential and possibilities, contribute to the overturning of negative education perceptions, and become a powerful tool in educators and parents' disposal.

Additionally, the efficient use of resources has the capacity to not only increase the outreach of teaching training systems, but also to articulate theory and practice and to support teachers in acquiring a practical reflection (Thakrar et al., 2009).

---

[27] *www.oecd.org/dataoecd/4/35/49850576.pdf*

[28] COUNCIL RECOMMENDATION of 28 June 2011 on policies to reduce early school leaving 2011/C 191/01. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011H0701%2801%29

[29] http://ec.europa.eu/education/school-education/doc/earlycom_en.pdf

5.5.4 Easier access to education resources

Science education resources have the potential to extend access to knowledge worldwide. A number of barriers though seem to stand in the way preventing them from being widely adapted and exploiting their full potential.

The obstacles that need to be addressed and dealt with in order to facilitate the access to these resources can be organized in the following categories:

- Social, awareness, policy, attitude, cultural:
  - *Access in terms of awareness*: Lack of awareness around the use and advantages of education resources can negatively preoccupy users and discourage them from looking into the new perspectives and possibilities that education resources have to offer.
  - *Access in terms of local policy/attitude:* Lack of policies or the existence of inefficient policies can also pose barriers to the efficient use of resources.
  - *Access in terms of language:* Lack of translations or users' inability to understand and speak the language of the resource can limit its use and outreach.
  - *Access in terms of relevance:* Identifying the resource that fits best an educator's or learner's needs is only possible through the use of meta-dating and OERs.
- Legal:
  - *Access in terms of licensing:* Need to provide teachers with appropriately licensed *education* resources licenses allowing them to make use of the resources, change/adopt them and then re-share them. Information on the various types of licenses and their implications is also needed.
- Technical: provision of OER:
  - *Access in terms of file formats:* Need to provide resources in easy to use and common file *formats* that educators can easily access, incorporate and use in their classes (i.e. doc, odt, rtf, pdf, ppt, odp, xls, ods, movetc)
- Technical: receiving OER:
  - *Access in terms of infrastructure:* In many cases and parts of the world the lack of power, *computers* or even classes can totally prevent the access and use of education resources.
  - *Access in terms of internet connectivity/bandwidth:* Infrastructure might be available *but* low bandwidth and problematic/slow internet connection can form barriers.
  - *Access in terms of discovery:* Sometimes OERs are hidden, hard to find, not *searchable* or indexed, which keeps users away from accessing and using these resources.
  - *Access in terms of ability and skills:* Users need to have the right information and *skills* in order to access and successfully use certain OERs.

As we can see above, the access to education resources is challenged by a variety of factors, which need to be addressed and successfully dealt with in order to facilitate their use and adaptation by the potential user. An increase in the efficient use of education resources will only be made feasible when all concerned actors including policy makers, teachers training organizers and teachers' themselves will, each from its own perspective, be in a position to recognize and deal with the above barriers.

5.5.5 Skills and tools for teachers to find, select and use the right for them resources

In a continuously progressing education environment, teachers remain in the centre of the whole process. Now more than ever though, they need to be in a position to identify the various resources, understand their functions and role, use them wisely, and manage them effectively. For this reason teachers need to be trained to:

- **Efficiently search for resources:** In this light, reusing existing Open Educational Resources (OER) is the most efficient option as it is time and effort saving. In this way you avoid investing time and effort for something that has already been developed. Selecting the most appropriate OER to meet your needs is not that straightforward though. The CC (Creative Commons wiki) under the recommendations of the Commonwealth of Learning (2012), *Open Educational Resources (OER) for Open Schooling, Teachers' Guide*[30] suggests a few ways to facilitate educators in their quest of OERs. The list is certainly not explicit but proves the variety of platforms users have in their disposal:
- OER specific search
  - DiscoverEd (http://discovered.creativecommons.org/search/)
- OER repositories (few examples)
  - Curriki (http://www.curriki.org/)
  - OER Commons (http://www.oercommons.org/)
  - LeMill (http://lemill.net/)
  - Connexions (http://cnx.org/)
  - OpenCourseWare Consortium: Index of OCW Websites (http://www.ocwconsortium.org/courses/ocwsites)
  - JorumOpen (http://open.jorum.ac.uk/)
  - The Encyclopedia of Life (http://www.eol.org/)
  - Ariadne (http://www.ariadne-eu.org/)
- General search engines
  - Google search (http://www.google.com/advanced_search)
  - Yahoo! CC Search (http://search.yahoo.com/cc)
- MOOCs: With a plethora of high quality MOOCs available in various languages and on many subjects, it is no surprise that online education is on the rise. A selection can be found below.
  - Coursera (https://www.coursera.org/)
  - Udacity (https://www.udacity.com/)
  - Khan Academy (https://www.khanacademy.org/)
  - Edx (https://www.edx.org/)
- **Use repositories which facilitate their selection of educational resources:** In the digital era we live in, a search for resources can return millions of results on just one single topic. Selecting the most appropriate and relevant resource becomes then a

[30] http://www.col.org/resources/crsMaterials/osoer/Documents/OEROSTeachers-Guide.pdf

challenge on its own. Some of the criteria that teachers needs to be trained on using and taking into account throughout their own searches are:

- consider the expected student learning outcomes and standards described in their national curriculum
- consider the particular needs of their students
- do not expose students to highly offensive or obscene materials or themes
- ensure that curriculum resources are suitable for the age group using them
- consider the words, behaviour, images or themes of the resources in terms of the context:
  - impact on the audience age group
  - literary, artistic or educational merit of the material
  - intention of the author and general character of the material
  - how parents might react to their children being exposed to this content
  - standards of morality, decency, and propriety generally accepted by adults
  - impact on persons from different ethnic, religious, social and cultural backgrounds.

Examples of repositories are: *Scientix*, *LRE for schools* and the *Open Discovery Space* portals.

On European level, Scientix project[31] "*collects teaching materials and research reports from European science education projects financed by the European Union under the 6th and 7th Framework Programs for Research and Technological Development (Directorate General Research), the Lifelong Learning Program (Directorate General Education and Culture), and various national initiatives*".

The Scientix platform facilitates regular dissemination and the sharing of news, know-how, and best practices in science education across the European Union.

Another useful tool is the Learning Resource Exchange (LRE)[32] portal which has been developed by European Schoolnet (EUN)[33]. LRE is a service that gives schools the opportunity to find educational content from different sources (countries and providers). Through it, Ministries of Education can access a network of learning content repositories and tools and are able to exchange learning resources that teachers of their countries can use. Ministries of Education in Europe support the evolution of the LRE and a number of European Commission funded projects, such as ASPECT[34], CELEBRATE[35], CALIBRATE[36] and MELT[37].

The ODS (Open Discovery Space)[38] project, is also an excellent source of OERs since it both provides an integrated access point for eLearning resources from dispersed educational repositories and it engages stakeholders in the production of meaningful educational activities. This is achieved with the use of a multilingual portal, which offers resources and services for the

[31] http://www.scientix.eu/
[32] http://lreforschools.eun.org/
[33] http://www.eun.org/
[34] http://www.aspect-project.net/
[35] http://celebrate.eun.org/
[36] http://calibrate.eun.org/
[37] http://info.melt-project.eu/ww/en/pub/melt_project/welcome.htm
[38] http://opendiscoveryspace.eu/

production of educational activities.[39]

5.5.6 Institutions that encourage and support the use of education resources

Initially (2001-2010), the OER movement was carried by various projects in international level which were run by educational institutions and individual experts (i.e. MIT Open courseware[28], FLOSS project[29]). The main problem these initiatives face is their sustainability, which prevents the mainstreaming of OER in national contexts. In the second decade (2011-2020) there are obvious efforts from many countries to develop a national OER approach (i.e. the National E-content and Curriculum Initiative[40] in India and Wikiwijs Program[41] in the Netherlands). Such efforts are imperative in order to make the mainstreaming of OER a reality. The sustainability of the OER approach should be a joined effort of the educational institutions that needs to be facilitated by the individual national setting.

These national efforts are of a great importance since they set the basis for the creation and development of the educational institutes of the future. These institutes will be in a position to support and foster environments where the education resources will be an integrated part of the education process.

The use of the education resources should also be supported and encouraged by the school management. School management, under the umbrella of the national policies and their adapted curricula, will be the ones guiding and supporting educators in their day-to-day efforts. The role of monitoring educator's progress, defining training needs, feeding the Ministry of Education with feedback and protecting the overall implementation of the educators efforts to use education resources, will then lie in the school management.

5.5.7 How to change

Several recommendations on the use of education resources have already been put together by various institutions. The *Paris OER declaration*[42] which has been published on June 2012, addresses a variety of issues focusing mainly on the role that policy makers have to play in this process. With this in mind, our list of recommendations attempting to cover all sides of this multidimensional issue can be found below:

- Development of policies and strategies which promote the use and production OER.
- Initiatives for promoting the finding and sharing of education resources through suitable tools based on standards that allow interoperability and diversity in their use.[43]
- Promotion of active participation of educators and learners in open education movements and support to the use of open resources as integral part of education.[44]
- Support of the use and understanding of open licenses through which open education

[39] http://opendiscoveryspace.eu/project
[40] http://poerup.referata.com/wiki/India#National_OER_initiatives
[41] http://www.wikiwijs.nl/
[42] http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/CI/CI/pdf/Events/Paris%20OER%20Declaration_01.pdf
[43] Naidoo, Vis (2013). OER Strategy – Taking it to a New Level. Commonwealth of Learning. Nairobi, Kenya November 19, 2013. Available at: http://www.col.org/resources/speeches/2013presentations/Pages/2013-11-19.aspx
[44] Li Yuan; Sheila Mac eill; Wilbert Kraan, Open Educational Resources – Opportunities and Challenges for Higher Education. Available at: http://wiki.cetis.ac.uk/images/0/0b/OER_Briefing_Paper.pdf

resources can be freely shared, used and edited. [45]

- Open education should become a common practice for governments and especially in colleges and universities.

Educate teachers and school managers in the use of Information and Communications Technologies (ICT) environments. Need to provide them with appropriate training on the use and application of education resources. This is going to be a continuously adaptable but of high significance process that will lay the foundations on the use of OER in the future.

[45] Cape Town Open Education Declaration: Unlocking the promise of open educational resources. Available at: http://www.capetowndeclaration.org/read-the-declaration

6. Inpts from literature review and other projects

At the start of the Go-Lab project, an extensive review of literature was carried out: it allowed to strengthen the rationale of the project and to define its place as a contribution to a global movement towards the innovation of science education. It also allows to identify relevant projects and potential partner organisations for the future development of GoLab. In this section, we report those results that are not specifically linked to the themes of the six challenges and opportunities papers summarised in section 5.

6.1 The broad debate on science education

Although there is consensus on whether science education should be a compulsory subject, there is little debate about its nature, even though curricula have been evolved (Osborne and Dillon, 2008). Three natural sciences (biology, chemistry and physics) are prevalent in school curricula but they do not cover the needs and the expectations of students who require a broad overview of the main principles and facts of science. The second main problem is that science education is not attractive for young people in a way that makes them eager to continue their studies in the field. Thus the goal of science education provided in schools should be the understanding if science principles and functions.

The knowledge not only of the content of the science but also of how science works is critical for the engagement with scientific issues and, as a result school curricula, suffer from difficulty in keeping the interest of students alive. In this framework knowledge is usually presented as fragmented concepts whereby the overarching coherence is not grasped. A new vision is needed which focus on the significance of science education and should give weight to the deep understanding through knowing not only the right or the wrong answer but also why it is. The situation described is depicted from the declining numbers of students who choose to continue their studies in the field of science education.

According to the current understanding of science education the experiences of students can be described as follows:

- The science curriculum lacks coherence and gives emphasis on the content without relating it with the contexts and the core idea of science.
- Students are not aware of the purpose of science education
- The methods and ways of assessment are irrelevant to the contexts learners can use science in practical terms and are based on memorization.
- Science and technology are not connected or even related
- Issues that permeate contemporary life are not touched by science curriculum.
- There is an over-reliance on transmission as a form of pedagogy with excessive use of copying.[46]

The existing mismatch between opportunity and action transmutes the meaning of Science Education as students do not learn how to think in a scientific way but they are being taught just facts and rules.[47] This divergence must be addressed if Science Education is to become a fulfilling learning experience and an essential part of the core education paradigm everywhere.

[46] Osborne J. & Dillon J. (2008). Science Education in Europe: Critical Reflections. Report to the Nuffield Foundation.
[47] Alberts, B. (2009). Editorial. Redefining Science Education. *Science Magazine*. 323, 437.

According to the recent report "Science Education in Europe: Critical Reflections" (Osborn & Dilon, 2008), 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*" (p.5).

What is needed is the re-imagination of science education in order to fit the modern world and satisfy the needs of the students (Kali & Linn, 2009). 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 standards of competence that can give records of students' competence. Science practitioners should be confident in harnessing the internet's potential in delivering interactive experiences, which have been either restricted in previous years or simply unavailable through the use of text books, videos or school laboratories. Rich scientific databases, eLearning tools and digital educational resources are freely available and can facilitate science learning. Universities and research centers can be the bodies through which the knowledge can be organized and tools for scientific research can be provided in order science to be made understandable to students. The investment on the new blood on science research and innovation should be planned by providing activities to students that are connected to the technological developments and practice problems and issues of the everyday life.If science introduced with that way it will be easier for students to understand it and use it as a tool to explore nature. Offering "hands-on" experiences which help students make real observations and come up with conclusions will develop their critical skills (Dziabenko and García-Zubía, 2013).

The choice of inquiry learning as the core approach of Go-Lab funds a broad and solid justification.

Inquiry based methods to learning science education, which involve experimentation and students' active participation, are necessary to motivate them in science education (e.g. Osborne & Dilon, 2008; Rocard, et al., 2007). Apart from that, inquiry skills are of great value on their own and therefore should be part of the curriculum. There is also overwhelming scientific evidence that inquiry leads to better acquisition of domain (conceptual) knowledge (de Jong, 2006). A recent meta-analysis reviewing 138 studies indicated a clear advantage for inquiry-based instructional practices over other forms of instruction in conceptual understanding that students gain from their learning experience (Minner, Levy, & Century, 2010).

Technology Enhanced Learning (TEL) approaches provides fabulous opportunities for inquiry as they offer tools that may be used for pedagogical purposes. Evidence is justifying that TEL inquiry environments provide students with truly effective learning opportunities, whereas large scale studies show that, on different outcome measures, TEL-based inquiry outperforms more direct approaches to instruction(de Jong et al, 2012). These results are evident only when scaffolds are used in the inquiry process, which gives them a vital role to the inquiry learning.

Currently a growing number of TEL inquiry environments have emerged that provide students with inquiry facilities together with integrated supportive structure and scaffolds (Vreman-de Olde et al, 2013).

Go-Lab inquiry spaces follow the approach of inquiry learning as exemplified in the projects mentioned above and in doing this we focus on (combining) remote and virtual labs and integrate them with supportive structure and scaffolds. In section 6.4 we zoom in on the virtues of remote and virtual laboratories and its combination and will then discuss the role of scaffolds.

The need for scientifically literate citizens is increasingly considered of primary importance in many countries. Science literacy and corresponding skills have the advantage that they provide citizens with the qualifications for a rational debate based on scientific facts.

The quest to improve science education faces various problems. In many places, the lack of resources (educational and financial) is linked with demotivated and not well-trained teachers and the growing unpopularity of science in young ages.

Scientific literacy for teachers refers to the (ICSU, 2011):

- "scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues;
- understanding of the characteristic features of science as a form of human knowledge and enquiry;
- awareness of how science and technology shape our material, intellectual, and cultural environments;
- willingness to engage in science-related issues and with the ideas of science, as a reflective citizen."

There is strong relation between scientific literacy and quality science education. Research has shown that the quality of science education is connected to the level of education attained (ICSU, 2011; p.8). As a result, school science education cannot meet the needs for improving public scientific literacy. On the other hand, informal and non-formal education, as essential parts of lifelong learning, are important elements of supporting the advantages in scientific discipline.

Bearing in mind that formal science education is provided in the educational system of each country and informal one is provided outside the classroom, what makes the difference in the quality of formal science education between diverse school settings is the availability of the equipment (laboratories, materials etc.) and the facilities (ICSU, 2011).

Science education should not be limited in the formal education setting but in the informal ones. Technological developments disappear the geographical constrains in learning and, as a result, the necessity of the informal education has been highly defended. The need of informing general public about technology and science in general has highlighted the necessity to invest and improve informal science learning.

It is also prominent that teaches' capabilities in science and in the use of contemporary technologies should be upgraded in order they can enhance student learning in science. Tertiary or post-school level science education is also in the same situation, as many teachers are ill-informed about current trends and developments in science, there is lack of laboratory facilities and the contents of the courses are outdated. As a result, learning is limited only to memorization exercises that just qualify students for a degree.

The situation described above highlights a critical point which refers to the poor pedagogical and subject knowledge of the teachers, which stress the need for their better training and the corresponding development of training service mechanisms. This would be a very promising initiative for the improvement both of teachers' professional development perspectives and the prestige and the social recognition of the profession. Furthermore, the evolution of the concepts of science and the changing information in science make the continuous learning by teachers a necessity.

The programs aiming at the professional development of the teachers' include some of the following activities (ICSU, 2011:p.16):

- "Deepening and broadening of knowledge of science content.
- Modelling the teaching of new content as well as best teaching practices (inquiry, constructivism, multiple intelligence, alternative assessments, etc.) to help teachers implement what they have learned as part of their professional development experience.
- Preparing teachers on how to engage their students in scientific investigations.
- Encouraging teachers to share successful teaching methods and materials that they have either developed themselves or are using from another source.
- Providing the opportunity for teachers to participate in courses on continuing education, science specializations, or towards a graduate degree.
- Integrating science with technology, social sciences, language and the arts.
- Establishing a strong foundation in the pedagogy and didactics of particular disciplines and their contribution to measurable improvement in student achievement.
- Devoting sufficient time, long-term support and resources to enable teachers to master new content and pedagogy and to integrate this knowledge and skill into their practice.
- Awareness of indigenous knowledge related to science.
- Encouraging education for sustainable development.
- Aligning with the standards and curriculum as defined within each country.
- Providing the opportunity for teachers to participate in research projects that assess the effectiveness of learning in specific settings
- Assessing, evaluating and reflecting on the professional development experience."

Internet provides a great opportunity for global science education as there is –usually freely-available a plethora of science educational resources both for learners and educators. Many of the resources available are offered as "Open Educational Resources" (OER), which creates challenges because they have license terms and give users the ability to re-use and re-mixing free of charge and with minimal attribution requirements.

6.2 Other trends affecting education at large

Other developments that carry weight to education and in particular to science education are the following: [48]

MOOCs: MOOCs have been in the past but recently, mainly in North America, they have become a trend. In pedagogical terms the method adopted involves video lectures, readings and staged assessment. MOOCs are a very promising tool which can be used to introduce a more innovative learning pedagogy in science education.

Badges to accredit learning: Badging, although being a recent development, can informally substitute accreditation schemes on condition that the tools and infrastructure will be improved in order to fit mainstream learning environments.

Learning analytics: Learning analytics involve the collection and analysis of large datasets relating to learners and their contexts. Learning analytics can be used to enhance learning design through the provision of information to new teaching methods and curricula.

[48] http://www.open.ac.uk/personalpages/mike.sharples/Reports/Innovating_Pedagogy_report_2013.pdf

Seamless learning: Seamless learning refers to the connection of the learning experiences across the contexts of location, time, device and social setting.

Crowd learning: Is an informal virtual model of learning that describes the learning from the expertise and opinions of others. Often, it is not recognized as a learning activity as it places the responsibility of learning on individual learners.

Digital scholarship: Refers to the innovations and changes introduced because of the use of digital and networked technologies.

Geo-learning: Sensors that are built into mobile devices and can determine the location of the user offer a great opportunity for interaction with the physical "real-world" and that way can both be an informal way of learning and enhance the formal learning.

Learning from gaming: There is strong connection between games and education and as a result teaching practices can benefit from the widespread use of gaming.

Maker culture: Maker culture emphasizes in social and playful learning and is based on the construction of artefacts. Its main functionality is the experimentation and innovation involved in such kinds of activities.

Citizen inquiry: Refers to the active participation of members of the public in structured investigations. It is a type of inquiry learning with mass collaborative participation and aims at creative knowledge building.

6.3 The use of remote and virtual laboratories for inquiry learning

This is the focus of the GoLab project and has been addressed in the DoW:

> *"The first question we should state is if online labs can replace real, physical, laboratories. Real laboratories are used in education for a multitude of reasons. Hofstein and Lunetta (2004), for example, described the values of real laboratory experiments for science education and mention understanding of scientific concepts and interest and motivation as main reasons for using laboratories. Balamuralithara and Woods (2009) list thirteen objectives for the use of physical laboratories which include awareness of safety procedures, and learning how to use human senses for observations. Also Feisel and Rosa (2005) present a list of objectives in real laboratories that include learning from failures and learning to work in teams. As an advantage for physical laboratories, some authors (e.g., Flick, 1993) emphasize a role for "physicality" for acquiring conceptual knowledge since it would trigger additional brain activities and also would enhance student motivation. However, studies that explicitly focused on the use of physical manipulatives (e.g., Chambers,Carbonaro, & Murray, 2008) do not find these advantages and also in comparison with virtual manipulatives the assumed advantages of physicality could not be found (e.g., Corter, Esche, Chassapis, Ma, & Nickerson,2011; van Klink, Wilhelm, & Lazonder, submitted; Yuan, Lee, & Wang, 2010; Zacharia&Olympiou,2011). Direct comparisons of the effects of physical and virtual laboratories on the acquisition of conceptual knowledge of the domain show that both approaches can be equally effective for learning but that in a number of cases virtual environments led to better results. Studies that found real and virtual laboratory experiments of equal effectiveness for acquiring conceptual knowledge are Wiesner and Lan (2004, chemical engineering), Klahr, Triona, and Williams (2007, physics (designing a car)), Winn, et al. (2006,oceanography), Zacharia and Constantinou (2008, phyiscs (heat and temperature)), Zacharia and Olympiou (2011, physic (heat and temperature)), and Corter, et al. (2011, mechanical engineering). Triona and Klahr (2003, phyiscs (springs)), who focused on the acquisition of inquiry skills, also found that simulated and real experiments were equally*

effective. Other work shows an advantage of virtual labs over real laboratories: Chang, Chen, Lin, and Sung (2008, optics) compared students who worked with a physical optics laboratory with students learning with simulations, Huppert, Lomask, and Lazarowitz Huppert (2002, microbiology), Finkelstein, et al. (2005, electrical circuits), and Bell and Trundle (2008, moon phases). Overall, we can conclude that the literature supports the idea that remote and virtual (online) labs can replace direct (or face to - face) access to real physical laboratories."

6.4 The distinctive virtues of remote and virtual labs

The fact that physicality is not relevant for learning makes that remote laboratories can be used instead of real physical labs. *Remotely-operated educational labs* ("remote labs") provide students with the opportunity to collect data from a real physical laboratory setup, including real equipment, from remote locations. As an alternative there are *virtual labs* that *simulate* the real equipment. Remote and virtual labs both have specific advantages for learning.

The first advantage of remote labs is that they do not mimic the real lab but students actually operate on real equipment. Remote labs thus give a more realistic view on scientific practice, including practical aspects such as occupied equipment etc. It, therefore, also give students a more realistic view on real lab work.

Another advantage of remote labs is that measurement errors are present by nature, whereas in virtual environments measurement errors are often ignored. Competency in a domain includes knowledge that measurement errors (of different kinds) exist and how to deal with them[49].

The reading of instruments in a virtual environment, for example, (with even a possibility to zoom in) is by nature easier than reading real instruments. Maisch et al (2009) showed that knowledge about measurement errors that is acquired outside a laboratory context doesn't easily transfer to the students' actions in a physical laboratory which suggests that real laboratory experiences may be important. Learning, however, is not all about cognitive challenges and outcomes; also enthusiasm and engagement play a role. Compared to research on cognitive outcomes results on motivational aspects of online and real labs is scarce but there are indications that real and remote labs lead to higher student motivation than simulated labs. Corter et al. (2011), for example, who compared a real, remote and simulated lab on the same (mechanical engineering) topic found no differences in learning outcomes but found that student appreciated the remote and real labs more because of their realism.

Concerning the ease of experimentation the advantages go in the direction of virtual labs. In virtual laboratories students can experiment without any costs and can more easily and repeatedly experiment so that ideas can be quickly tested and evaluated. Another advantage for virtual laboratories is that reality can be adapted to serve the learning process. Reality can both be simplified by taking out details (and thus lowering fidelity) or be "augmented" by adding specific features to reality (such as adding vectors to moving objects).

In conclusion, remote and virtual labs both have their specific virtues to bring to the learning situation; each of them also focusing on partly overlapping but also different learning goals[50]. Our next exploration is how to potentially combine remote and virtual labs.

[49] Toth, Morrow, & Ludvico, 2009
[50] Ma & Nickerson, 2006

6.5 The best of both worlds: Remote labs in combination with virtual experimentation facilities

Since remote labs are offered over electronically, remote labs already offer some of the advantages of virtual labs in the sense that remote labs can be extended by augmentations and cognitive scaffolds, thus gaining some of the evident advantages of virtual labs (see the next section). However, also in remote labs, experimentation is as time consuming as in real labs and, therefore, recent research started to develop and investigate combinations and sequences of the two.

Most of the work, however has been on placing both versions in order and most of those studies showed that a virtual lab preceding a real (or in our case) remote lab is advantageous for learning. From a more cognitive point of view there are indications that the combination works because students have to compare different types of representations. Jaakkola, et al (2010) report a study in which they videotaped students who constructed electrical circuits only in as simulated environments with students who first made this virtual construction and then made the same circuit in reality. These video data made clear that students in the combined condition profited from the fact that they had to compare two representations that sometimes differed and had to go into abstract reasoning to explain these differences. A similar finding was reported by Goldstone and Son (2005) who found that offering both abstract and concrete representations in a simulation helped the student understand the principle behind the simulation. In this study it appeared that students who moved from a concrete to an idealized simulation outperformed other students on immediate and transfer test. In Go-Lab we will search for different ways to combine remote and virtual experimentation facilities. In any case, both remote and virtual labs need scaffolds to function effectively.

6.6 The role of scaffolds in inquiry learning with online labs

Scaffolding refers to support (dedicated software tools) that helps students with tasks or parts of a task that they cannot complete on their own. Scaffolds aim at the different learning processes that constitute inquiry learning. For example, they can help students to design experiments (Lin & Lehman, 1999), make predictions (Lewis, Stern, & Linn, 1993), formulate interpretations of the data (Edelson, Gordin, & Pea, 1999), reflect upon the learning process (Davis, 2000), plan and structure their work (van Joolingen, et al., 2005), and monitor what has been done (Hulshof,Wilhelm, Beishuizen, & van Rijn, 2005). We can also scaffold the complete process by having student work with an inquiry cycle (Manlove, Lazonder, & de Jong, 2007). In any case meta-analyses (Alfieri, et al., 2011) show that inquiry learning is only productive when the inquiry process is structured and scaffolded.

6.7 Collaboration in lab work

In addition to being an excellent context for learning activities, lab work also forms a unique setting to develop soft skills such as autonomy and collaboration (Corter et al, 2011). One of the intended outcomes of learning with Go-Lab online labs is that students acquire those skills. Looking at this issue from the other side, collaboration also helps to raise students' conceptual knowledge and inquiry skills in an inquiry learning situation. There is a growing awareness that knowledge construction processes are influenced by the social setting in which they take place. "Collaboration is widely used and recognized as a way to enhance student learning (Lou et al., 2001). The positive effects of collaboration can be explained by the fact that engagement in a collaborative learning task provides students with the opportunity to talk about their own understandings and ideas."

"During inquiry learning, students must make many decisions (e.g., which hypothesis to test, what variables to change), in a collaborative inquiry learning setting, students are invited to share these plans and ideas with their partner(s). This means that when students work collaboratively, they need to externalize their ideas; they must provide arguments and explanations so that their partner is able to understand and evaluate their ideas and plans" (Teasley, 1997). Externalizing thoughts and ideas is believed to increase students' awareness of flaws and inconsistencies in their own reasoning or theories and to stimulate students to revisit their initial ideas. A study by Okada and Simon (1997) compared the inquiry learning behaviour of individual students and dyads in a molecular biology learning environment. They found that dyads considered more alternative hypotheses and carried out more useful experiments than individuals. The generation of an alternative hypothesis was often triggered by a question or a remark from the learning partner. In a recent studies Kolloffel, de Jong, and Eysink (2011) confirmed the effectiveness of collaboration in inquiry learning settings. Specific scaffolds might assist the collaboration process. For example, Gijlers and de Jong (2009) introduced a tool that visualized students' conflicting ideas and prompted students to think about conflicting ideas. In Go-Lab, in order to minimize the change in classroom scenarios, while maximizing the advantages of lab activities, the collaborative learning part is considered as a face-to-face activity limited to classmates.

Go-Lab pedagogical scenarios will provide guidelines on how to structure and scaffold collaborative inquiry with online labs in the classroom.

6.8 Conclusions from the review of the literature

The general conclusions from this literature review are:

1. Inquiry based approaches are more effective for acquiring conceptual domain knowledge than traditional more directive forms of instruction,
2. For learning domain knowledge, real, physical, laboratories are not necessary and can be replaced by remote or virtual (online) laboratories,
3. Remote laboratories and virtual laboratories to a large extent have overlapping characteristics and advantages, but also a few specific virtues, such as ease of experimentation for virtual labs and motivations in remote labs. Recent studies have shown that combining remote and virtual labs might render most effective form of inquiry learning.
4. Inquiry learning in remote labs will only be effective is the inquiry process is structured and/or scaffolded.
5. Collaboration between peer students is an important learning asset that can be realized in working with online labs, but this collaboration is not necessarily carried out online as well.

Finally, when we consider the place of inquiry learning and the use of remote and virtual laboratories on line, we can see how these are coherent with the broader evolution scenarios of education, in which the search of meaning, the validation of available information, process knowledge and skills, critical thinking are more essential in education than factual knowledge, broadly available online.

The issue of learning assessment becomes therefore critical, because what is taught is what has to be assessed, and if assessment is not changing very little can be changed in curriculum and learning practice. This has to do also with the need/opportunity to integrate informal learning into school education and the difficulty to do this if learning assessment is strictly linked to a given body of knowledge that is taught at school.

The huge potential of ICT to enrich and innovate science teaching is therefore threatened by rather obsolete practices of assessment that condition all the rest: policy makers, although alerted by several studies, have not yet implemented the necessary change in official learning assessment that would possibly open the door to scalable change in science education.

7. Results overview, conclusions and open questions

This section synthesises the main conclusions the main conclusions of the study and proposes a set of open questions on which the Go-Lab project will continue to mobilise stakeholders in order to achieve a better understanding of its long term success conditions in a quickly changing environment.

7.1 Results overview and conclusions

1. The Future Challenges Study confirms the relevance of the aims and the approach adopted by Go-Lab: its vision of future education and of the potential of IC to contribute to it are shared by existing research, stakeholders' views and teachers' expectations; the specific contribution to science education renewal at EU and international level is significant in itself and integrated in a system of large-scale initiatives supported by the European Union and coherent among themselves.
2. There is a broad consensus also on what are the main challenges to be addressed and the main areas of change: curricula reform and assessment methods, organisation of contents around competences and innovative pedagogy; teachers' competences and motivation to change, learners motivation, organisational routines and constraints, availability of technology and use of resources. Addressing each of these challenges is possible and small-scale experiences exist to demonstrate good practice, but system-scale innovation is the real challenge.
3. It is difficult to address all the challenges at the same time, but it is very unlikely that a fragmentary approach will reach the objective of large scale innovation. Over thirty years of policies in the field of ICT for education show that an integrated approach is necessary to produce real impact: technology infrastructure without teachers' competence and motivation will not change the way science is taught, nor a change in pedagogical practice without a change in curriculum and learning assessment. It is therefore fundamental that the Go-Lab large scale piloting is institutionally supported in each participating country, in the attempt to combine the bottom-up approach of the participating school with the relevant "innovation policy" framework of the country. The virtuous circle between research, policy and innovative practice must be demonstrated by the project.
4. Stakeholders involvement is much more than a side aspect in project implementation: without stakeholders' attention and consensus a mechanistic implementation of innovative experiences will not produce significant impact after the end of the project: stakeholders must not only know about Go-Lab but support its efforts, and to do this they need to gain "ownership" of the pilot experiences and be allowed to get an important role in its future implementation.
5. Formative Evaluation and Quality Assurance are two fundamental features of the Go-Lab project because they allow/oblige partners to keep a constant communication channel open among WPs/partners and, even more importantly, with the stakeholders that are one of the keys for project impact in the medium and long term. If we look beyond he project "contractual life" –that is relatively long and already contains quite ambitious quantitative and qualitative objectives- the real success will consist on a large-scale follow up of the project results and their integration into EU and national policies for modernisation of science education. To reach this goal a systemic and transparent documentation of the working cycle of the project, of difficulties and improvements, of lessons learnt is of the upmost importance.

6. Finally, Go-Lab has a lot of challenges to face in the next years, and a real concrete opportunity to be relevant in view of a systemic change of science education in Europe. Making this opportunity a reality will depend on the conditions identified above and probably others that will emerge in the next years of the project. Every identified challenge will drive project activities planning and, in the meantime, some issues that are important and still open will be addressed.

7.2 Open Questions

In the writing of the Challenges and Opportunity Papers, several open issues have been identified, that deserve further attention and will be addressed in the next years. We have grouped them in four broad categories:

1. Consensus and scope (C)

C1 How diffused is the consensus on the need and the way to change science education?

C2 How integrated should the debate on science education be in the broader debate on transformation of school education (in order to achieve policy attention)?

C3 Is the evolution towards “openness” unavoidable?

2. Assessment and evaluation (A)

A1 Can international standards of assessment such as Pisa produce a positive impact on how science is taught and learnt?

A2 How to evaluate effective use of educational resources? Is it possible to think of one global standard?

3. Scalability (S)

S1 How can (even large) projects get the attention of policy makers and influence future policy?

S2 Is there a documentable virtuous circle between bottom-up and top-down approaches for scalability of innovative good practice?

S3 What policies and what practical steps are needed to prepare school environments for open educational resources and open educational practices, including recognition of learning outcomes?

4. Teachers and Schools (T)

T1 What is the relevance of remote labs as perceived by teachers? Do they see all the benefits? Do they fear anything?

T2 Are teachers equipped with the competences required to understand the learning continuum, to recognise the different skills of learners, to choose among different strategies, to plan pedagogical actions?

T3 Are teachers and schools equipped for widespread adoption of online labs?

T4 Is teachers’ training adequate to diversity and openness planning.

References

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning?. Journal Of Educational Psychology, 103(1), pp. 1-18. doi:10.1037/a0021017

Bakia, M.; Anderson, K.; Heying, E.; Keating, K.; Mislevy, J.: Implementing Online Learning Labs in Schools and Districts: Lessons from Miami-Dade's First Year. Menlo Park, CA: SRI International. November, 2011. Available at: http://www.sri.com/sites/default/files/brochures/implementing_online_learning_labs.pdf

Balanskat, Blamire & Kefala (2006). *The ICT Impact Report A review of studies of ICT impact on schools in Europe*. Available at: http://ec.europa.eu/education/doc/reports/doc/ictimpact.pdf

Becta. (2004). A review of the research literature on barriers to the uptake of ICT by teachers. Available at: http://partners.becta.org.uk/page_documents/research/barriers.pdf

Betts, S. (2003). Does the use of ICT affect quality in learning science at Key Stage 3?'Studies in Teaching and Learning, pp. 9-17.

Black, A.E. and Deci, E.L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective, Science Education, Vol. 84, Issue 6, pp. 740-756.

Bingimlas, K. A.: Barriers to the Successful Integration of ICT in Teaching and Learning Environments: A Review of the Literature. In: Eurasia Journal of Mathematics, Science & Technology Education, 2009, 5(3), pp. 235-245. Available at: http://ejmste.com/v5n3/EURASIA_v5n3_Bingimlas.pdf

Cape Town Open Education Declaration: Unlocking the promise of open educational resources. Available at: http://www.capetowndeclaration.org/read-the-declaration

Commonwealth of Learning (2012), Open Educational Resources (OER) for Open Schooling, Teachers' Guide

Corter, J.E., Esche, S.K., Chassaspis, C, Ma, J, Nickerson, J.V. (2011). Process and learning outcomes from remotely-operated, simulated, and hands-on student laboratories. Computers & Education, Vol 57, Issue 3, pp. 2054-2067

Department of Education and Early Childhood Development, Victoria (2011), Selecting Teaching and Learning resources

de Jong, T. (2006). Technological Advances in Inquiry Learning. Science, Vol 312(5773), pp. 532-533.

de Jong, T, Weinberger, A., Girault, I. et al (2012). Using scenarios to design complex technology-enhanced learning environments. Education Tech Research Dev. Available at http://users.edte.utwente.nl/jong/ETRD%20in%20press.pdf

Dziabenko Olga & García-Zubía Javier (2013). IT Innovative Practices in Secondary Schools: Remote Experiments. Bilbao: University of Deusto.

EACEA; Eurydice Key Data on Learning and Innovation through ICT at School in Europe, 2011 Edition

Edelson, DC, Gordin, D.N., & Pea, R.D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. Journal of the Learning Sciences, 8(3/4) pp. 391-450.

Ertmer, P.A. (1999). Addressing first-and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development, 47*(4), 47-61.

ESHA (2014). Resistance 2 change. Esha Magazine May/June 2014. Available at: http://www.esha.org/sites/default/files/eshamagazinedownloads/Esha%20Magazine%20June%202014.pdf

European Commission /EACEA/ Eurydice , 2012. Developing Key Competences at School in Europe: Challenges and Opportunities for Policy. Eurydice Report. Luxembourg: Publications Office of the European Union

Ferrari, A. (2012). JRC technical reports. Digital Competence in Practice: An Analysis of Frameworks. Joint Research Center, European Commission. Report EUR 25351 EN. Available at: http://www.ifap.ru/library/book522.pdf

Gagne, R. M., (1985) The Conditions of Learning and Theory of Instruction. New York: CBS College Publishing.

Gahala, J.: Critical Issue: Promoting Technology Use in Schools. Date posted: October, 2001. Available at: http://www.ncrel.org/sdrs/areas/issues/methods/technlgy/te200.htm

Gender, Diversities, and Technology Institute, Education Development Centre, Inc.(2005) , *Effective Access, Teachers' use of digital resources in STEM teaching, Katherine Hanson and Bethany Carlson*

Goldstone, R. L., & Son, J. Y. (2005). The transfer of scientific principles using concrete and idealized simulations. The Journal of the Learning Sciences, Vol 14,pp. 69-110.

Gomes, L.; Bogosyan, S.: Current Trends in Remote Laboratories. In: IEEE Transactions on Industrial Electronics, Vol. 56, No. 12, pp. 4744-4756. December 2009. Available at: ftp://161.24.19.221/ele/elisa/Leitura/2009_Gomes_Current_Trends_in_Remote_Laboratories.pdf

Hannon, V. (2007). "Next Practice" in education: a disciplined approach to innovation, p. 9. Available at: http://www.innovationunit.org/sites/default/files/Next%20Practice%20in%20Education.pdf

http://www.fisica.unina.it/traces/attachments/article/149/Nuffield-Foundation-Osborne-Dillon-Science-Education-in-Europe.pdf

- http://www.infed.org/thinkers/polanyi.htm
- http://www.league.org/gettingresults/web/module1/learning/how_know_students.html
- http://www.peter.baumgartner.name/addedValuesPI/stories/storyReader$832
- http://www.tlrp.org/pub/documents/TLRP_Schools_Commentary_FINAL.pdf
- http://www.tlrp.org/pub/documents/TLRP_Schools_Commentary_FINAL.pdf

Hulshof, C.D., Wilhelm, P., Beishuizen, J.J., & Van Rijn, H. (2005). FILE: A Tool for the Study of Inquiry Learning. Computers in Human Behavior, 21 (6), pp. 945-956.

ICSU (2011). Report of the ICSU Ad-hoc Review Panel on Science Education. Available at: http://www.icsu.org/publications/reports-and-reviews/report-of-the-icsu-ad-hoc-review-panel-on-science-education/Report%20on%20Science%20Education%20final%20pdf.pdf

Johnson,L.,Adams Becker,S., Cummins, M.,Estrada V.,Freeman, A., andLudgate, H.(2013). NMC Horizon Report: 2013 K-12 Edition. Austin,Texas: The NewMedia Consortium

Joint Research Centre – Institute for Prospective Technological Studies; Title: Digital Competence for Lifelong Learning; Authors: KirstiAla-Mutka, Yves Punie and Christine Redecker

Joint Research Centre – Institute for Prospective Technological Studies; Title: Digital Competence in Practice: An Analysis of Frameworks; Author: Anusca Ferrari

Joseph, J. E.: The barriers of using educational technology for optimizing the educational experience of learners. In: The Online Journal of New Horizons in Education, Vol. 3, Iss. 2, pp. 51-57. April 2013. Available at: http://www.tojned.net/pdf/v03i02/v03i02-06.pdf

Kali, y., & Linn, m. (2009). Designing Coherent Science Education: Implications from Curriculum, Instruction, and Policy. Teachers College Press.

Kastis, N. (2007). Observing the e-Learning phenomenon: The case of school education. Analysing the transformative innovation of e-Learning. eLearning Papers, No 4, May 2007, ISSN 1887-1542.

Körös-Mikis, M. (2009). Defining Innovative Pedagogical Practice. Available at: http://www.ofi.hu/studies-articles-090617/defining-innovative

Lazonder, A., Manlove, S., & De Jong, T. (2007). Use and usefulness of regulative scaffolds during collaborative inquiry learning. Paper presented at the twelfth European Conference for Research on Learning and Instruction, August 28 – September 1, Budapest, Hungary.

Lewis, E. L., Stern, J.L., Linn, M.C. (1993). The effect of computer simulations on introductory thermodynamics understanding, Educational Technology, Volume XXXIII, Issue 1, pp. 45-58.

Lin, X.D., & Lehman, J. (1999). Supporting learning of variable control in a computer-based biology environment: Effects of prompting college students to reflect on their own thinking. Journal of Research In Science Teaching, 36(7), pp. 1–22.

LLWings Teacher training modules, http://llwings.euproject.org/llwings/

Lou, Y., Abrami, P.C. and d'Apollonia, S. (2001). Small Group and Individual Learning with Technology: A Meta-Analysis. Review of Educational Research, Vol. 71, No. 3, pp. 449-521.

Maisch, C., Ney M., van Joolingen W. & de Jong T. (2009) Inconsistent reasoning about measurement by undergraduate physics students. Proceedings de la conférence ESERA International Conference of the European Science Education Research Association, Istanbul, Turquie, août 2009

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474-496. doi: 10.1002/tea.20347

Mulder, F. (2013). The LOGIC of National Policies and Strategies for Open Educational Resources. The International Review of Research in Open and Distance Learning. 14, 2, pp. 96-105. Available at: http://files.eric.ed.gov/fulltext/EJ1008095.pdf

Naidoo, Vis (2013). OER Strategy – Taking it to a New Level. Commonwealth of Learning. Nairobi, Kenya November 19, 2013. Available at: http://www.col.org/resources/speeches/2013presentations/Pages/2013-11-19.aspx

National Science Education Standards: An Overview, p. 18. Available at: http://www.nap.edu/openbook.php?record_id=4962&page=12

Niemiec, C.P. and Ryan, R.M. (2009). Autonomy, competence, and relatedness in the classroom. Applying self-determination theory to educational practice. Theory and Research in Education. Vol. 7, No. 2, pp. 133-144.

Observing evolution in learning through 11 domains of change. Which role can ICT play in matching the challenges of the xxi century? VISIR vision report y1. Project: Vision, Scenarios, Insights and Recommendations on how ICT may help making lifelong learning a reality for all, 2012 (Acronym: Visir). Available at: http://visir-network.eu/wp-content/uploads/2013/01/VISIR_Vision_Report_2012.pdf

Okada, T. and Simon, H.A. (1997). Collaborative discovery in a scientific domain. Cognitive Science, 21, pp. 109-146

OECD (2012), *Preparing teachers and developing school leaders for the 21st century: Lessons from Around the World*

Official Journal of the European Communities "Council Resolution" of 27 June 2002 on Lifelong Learning (2002/c 163/01)

Osborne J. & Dillon J. (2008). Science Education in Europe: Critical Reflections. Report to the Nuffield Foundation. Available at: http://efepereth.wdfiles.com/local--files/science-education/Sci_Ed_in_Europe_Report_Final.pdf

Osborne, J. &Dilon, J. (2008). Science Education in Europe: Critical Reflections. A report to the Nuffield Foundation.

Pelgrum, W. J. (2001). Obstacles to the integration of ICT in education: results from a worldwide educational assessment. Computers & Education, 37, pp. 163-178.

Project: Large Scale Experimentation Scenarios to Mainstream eLearning in Science, Mathematics and Technology in Primary and Secondary Schools, 2013 (Acronym: Inspiring Science)

Project: Vision, Scenarios, Insights and Recommendations on how ICT may help making lifelong learning a reality for all, 2011 (Acronym:Visir)

Psycharis, S. (2013), Exploring the Effects of the Computational Experiment Approach to the Epistemic Beliefs, the Motivation, the Use of Modeling Indicators and Conceptual Understanding in Three Different Computational Learning Environments. Journal of Education and Training Studies, 1, 1, pp. 69-87.

Ritter, M. E.: Barriers to Teaching Introductory Physical Geography Online. In: Review of International Geographical Education Online, RIGEO, Vol. 2, No. 1. Spring 2012. Available at: http://rigeo.org/vol2no1/2.4.RIGEO-VOL.2.NO.1-4.pdf

Robert E. Yager, Science Education - Overview, Preparation of Teachers, Available at: http://education.stateuniversity.com/pages/2403/Science-Education.html

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H. and Hemmo, V. (2007). Science education now: a renewed pedagogy for the future of Europe. European Commission, ISBN – 978-92-79-05659-8. Available at http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

Rudinsky, J.; Law, E.: Go-Lab Project Internal Deliverable G3.1: Report on Analysis of Online Labs User Surveys: Implications for the Go-Lab Portal Design. March, 2013.

Schanda, F.; Dikke, D.; Mueller, N.: Personal Learning Management Systems (PLMS): Concept, Classification, Evaluation. In: Proceedings of the 5th International eLBa Science Conference in Rostock, Germany, June 21-22, 2012.

Schreiner, C. and Sjøberg, S. (2004). Sowing the seeds of ROSE: background, rationale, questionnaire development and data collection for ROSE (The Relevance of Science education) - a comparative study of students' views of science and science education, Acta Didactica 4/2004, Oslo, University of Oslo. Available at http://www.uv.uio.no/ils/english/research/projects/rose/actadidactica.pdf

Science Education in Europe: Critical reflections_a report to the Nuffield Foundation; Jonathan Osborne, Justin Dillon_King's College London

Science, vol 323, 2 January 2009, www.sciencemag.org (Alberts, 2009)

SEEQUEL (2004). Sustainable Environment for the Evaluation of Quality in E-Learning. Quality guide to the non-formal and Informal learning processes. Available at: http://www.menon.org/wp-content/uploads/2012/11/SEEQUEL-TQM-Guide-for-informal-learning.pdf

SeeQuel "Quality Guide to non-formal and informal learning" 2004, http://www.menon.org/publications/TQM%20Guide%20for%20informal%20learning.pdf

Shumow, L. and Schmidt, J.A. (2013). Enhancing adolescents' motivation for science. Research-based strategies for teaching male and female. Corwin Press Inc (Verlag), ISBN: 9781452269696.

Teasley, S.D. (1997). Talking About Reasoning: How Important Is the Peer in Peer Collaboration? Discourse, Tools and Reasoning. NATO ASI Series Volume 160, pp. 361-384

Thakrar, J., Zinn, D. & Wolfenden, F. (2009). Harnessing Open Educational Resources to the Challenges of Teacher Education in Sub-Saharan Africa. The International Review of Research in Open and Distance Learning, 10, 4. Available at: http://www.irrodl.org/index.php/irrodl/article/view/705/1319

UNESCO (2012), Preamble of OER Recommendations

UNESCO (2009), Current Challenges in Basic Science Education. Available at: http://unesdoc.unesco.org/images/0019/001914/191425e.pdf

Van Joolingen, W. R., De Jong, T., Lazonder, A. W., Savelsbergh, E. R., & Manlove, S. (2005). Co-lab: research and development of an online learning environment for collaborative scientific discovery learning. Computers in Human Behavior, 21, 671.

Velek P & Pérez-Rubio, V. J. (2013) "Sharing Open Educational Resources in Multilanguage Repositories - the Learning Resource Exchange and Scientix", LINQ2013

Vreman-de Olde, G.C., de Jong, T., Gijlers, H.(2013). Learning by Designing Instruction in the Context of Simulation-based Inquiry Learning. Educational Technology & Society, 16 (4), 47-58.

VISIR Project, Teaching, teachers competencies and communities of practice. Available at: http://visir-network.eu/vision/teaching/

VISIR Project, Valuing learning, motivation, awareness and value of learning. Available at: http://visir-network.eu/vision/valuing-learning/

Annexes

Annex 1. GoLab Discussion Papers (separate files)

1. GoLab Discussion Paper n. 1, “The future of science education”
2. GoLab Discussion Paper n.2, “How to motivate teachers and learners to use online labs”
3. GoLab Discussion Paper n.3, “How to adapt pedagogical practices”
4. GoLab Discussion Paper n.4, “How to lower organisational and technical barriers”
5. GoLab Discussion Paper n.5, “How to raise digital competences of the teachers and students”
6. GoLab Discussion Paper n.6, “Effectiveness of the use of digital educational resources”

Annex 2: List of the experts interviewed

Name	**Position**	**Institution**	**Country**
Roger Ferlet	Researcher	Institut d'Astrophysique de Paris	France
Carl Pennypacker	University professor	University of Berkeley	USA
Pamela Gay	University professor	Southern Illinois University	USA
Serafim Spanos	Teacher	Iolkos High School, Greek Astronomers Society	Greece
Mick Storr	Education and Outreach Coordinator	CERN	switzerland
Costis Kontogiannis	School Head	Peiramatiko Gymnasio Plakas	Greece
Fred Verboon	Director	ESHA – European School Heads Association	Belgium
Sylvia Peters	Head Researcher	Kennisnet	The Netherlands