Go-Lab

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Future Challenges Report

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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. Therefore, results and 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 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 here reported:

1. The Future Challenges Study confirms the relevance of the aims and the approach adopted by Go-Lab in terms of its vision of future education and of the potential of ICT to contribute to it. The project's specific contribution to science education renewal at EU and international level is seen as significant in itself and its integration into a system of large-scale initiatives supported by the European Union that are coherent among themselves is seen as timely.

2. There is a broad consensus also on what the main challenges and the main areas of change are. In particular, 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. Although it is difficult to address all challenges simultaneously, this is still the best approach in order to 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 GoLab large scale piloting is supported by the relevant institutions in each participating country, 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 demonstrated 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 Go-Lab but also support its efforts, and 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 allow/oblige partners to keep an open constant communication channel 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 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 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 utmost 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.

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1. Introduction

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. Connected fieldwork and desk research activities are also identified that aim at identifying 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 at the moment of writing the Go-Lab proposal, 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 activity of the Go-Lab Project and represents a Milestone in WP6 – Community Building and Support. However, since the participatory engagement and prospective study continue during the life-cycle of the project, partners engaged in these parts of the project will periodically update and enrich thir 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 themes 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 works 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 school transformation 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 tis tension between points of view is desireable and even necessary not only to gain 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 original hypotheses and the methods 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 original hypotheses of the Go-Lab project and of the study on future challenges

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 Methods Adopted

This report is the result of four groups 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 its relevance interm of impact on the project, is that visionary workshops have helped the GoLab project partners approach teachers, which can also sonstitute a preliminary pilot schools recruitment process. This is a further example of the interaction between WP6 and WP7.

1. To collect stakeholders' views on the future of science education and the specific role that could be played by online laboratories, and then to contribute to task 6.1 (Critical Framework Thinking).
2. To collect feedback on the pedagogic, 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 create 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.

In actual fact, most of the participants were teachers who 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 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 methodological proposal, and a preliminary list of barriers to large scale implementation was identified.

3.2 Feedback on the Go-Lab proposal

The Go-Lab project and its outcomes correspond to certain needs of teachers. In all cases, the project was received very positively and the participants regard its outcomes as valuable.

Furthermore, the participants thought that visionary workshops were also interesting and engaging.

Almost all participants 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 agree that simple graphics and the use of small icons and colours will help them find services more easily. Teachers liked the design and underlined the need for a simple interface with not much text.

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

Most of the participants would recommend the Go-Lab activities to their colleagues. All of the participants agree 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 useful to have.

Participants suggested including 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 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 infrastructure 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.

Science education is evolving once again towards a focus on mastering basic concepts and skills that can be used in new situations. In order to truly accomplish this, context needs to be established first. Concepts and process skills are desirable end points. But if real learning is to occur, concepts and skills cannot be approached directly and used as organizers for courses and instruction. Without the proper background, students do not understand and are rarely able to use the information and skills that are taught. This explains why science lacks popularity and why most students stop their study of science as soon as they are permitted to do so. Little is gained by simply requiring more for a longer period of time.

Another trend identified and commented on by stakeholders is the open inclusion of technology with the study of science. Underlining the contrast between the two can help develop an awareness of the history, philosophy, and sociology of both. Since more students are interested in technology than in science, including technology within science education can provide a vehicle for getting students more involved with basic science. Instead of authorities proclaiming science as important and useful, students discover that for themselves as they develop and use new technologies.

The involvement of more people and organizations in the process of educating youth is another important trend. Responsibility for setting science goals, choosing instructional strategies, determining curriculum structure, and defining assessment efforts must rest with teachers as well as with students. Outside stakeholders must be involved and are integral to the plan to improve science education.

Major issues include how to evaluate and enlarge goals, how to change instruction, how to move assessment from testing for memory and repetition of procedures to making these constructs and skills as part of the mental frameworks of the students. When does real learning pass from mimicry to understanding and personal use?

Engaging students' minds requires changes that are essential to current reform efforts. Such engagement is accomplished when:

- Students help define the content–often by asking questions.
- Students have time to wonder and to find interesting pursuits.
- Topics often have strange features that evoke questions.
- Teachers encourage and request different views and forms of expression.
- The richest activities are invented by teachers and students.
- Students create original and public products that enable them to be experts.
- Students take some actions as a result of their study and their learning.
- Students sense that the results of their work are not predetermined or fully predictable.

4.3 Synthesis of the debate

Major controversies remain. Certainly most educators remain committed to the model of relying on the science found in textbooks, state curriculum frameworks and standards documents. They are committed in spite of the research evidence that highlights the advantages of new approaches to learning and new ways of measuring learning and understanding new learning approaches. Humans tend to resist change–even when they know it will occur. It is unfortunate that science educators do not lead in the attack on the unchanging curriculum and lack of attention and use of the new information on how humans learn.

Through science learning, students will learn to define, refine and resolve problems and ideas. They will learn to do this through practical data gathering, collecting information from a range of sources, transforming that data to make broader generalizations, explaining their outcomes and justifying their positions. They will start to realize the limits of their data and their arguments and how they might be developed further.

Students will come to know basic concepts of science, how to use them to explain and understand the world around them, and how to change this world. This is the sort of learning most closely related to current school science around the world. However, as we have seen, the contexts for learning these concepts should relate to the lives and concerns of the students, rather than to arbitrary abstractions. From the perspective of science, students should develop key ideas and understand their inter-connectedness, such as the relationship between the macro and micro-structures of materials and their properties, the concept of energy, ideas about cells and interdependence in biological systems. This knowledge is accepted by practicing scientists, which they have built on the available knowledge following accepted methods. Scientists also know that science does not have all the answers and that scientific knowledge is continuously under transformation as new information is acquired.

The debate about process and content has a long history going back to the start of modern schooling in the nineteenth century. Programs such as TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Students' Asessment) may imply a universalizing, homogenizing or globalizing of content as nations try to improve their standing in such surveys. However, the ROSE (Relevance of Science Education) Review[1], which covers both developing and developed countries, argues that a new school science has to match the context where the students learn. They say such an approach draws on current learning theory, which argues for the efficacy of situating learning in the students' contexts.

The recognized lack of relevance of the science and technology curriculum is probably one of

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[1] Schreiner and Sjøberg 2004, see References

the greatest barriers for good learning as well as for interest in the subject. The outcome of the project will be empirical findings and theoretical perspectives that can provide a base for informed discussions on how to improve curricula and enhance the interest in S&T in a way that:

- Respects cultural diversity and gender equity
- Promotes personal and social relevance

  Empowers the learner for democratic participation and citizenship[2]

School science should not be based on abstract concepts; rather it should build on situations connected to the lives of the students. As always, there is the tension between the local, namely student relevance, matching the interests of the students and their contexts; and the wider context, the need to prepare students to go beyond their immediate environment to a wider view of the world and its possibilities. This tension can be alleviated by helping students not only to learn the processes and content of science but also to help them reflect on their learning so that they will be better able to go beyond their immediate contexts. Through their science lessons, students in basic education should learn to search for information from a variety of sources both first- and second-hand; to sort and classify; to explain their findings; to offer conjectures and refutations of their views and those of their peers; to suggest hypotheses; to devise and carry out investigations to verify these hypotheses, evaluate the outcomes of such investigations, and to be able to connect such material together to bring their work to a conclusion and suggest new opportunities for future investigations. Supporting the students to develop such learning will require a change in the way that many teachers go about their work. The focus is on the learning of the students.

The ROSE Review also reminds us 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"[3]. This is something that most educators and students would agree with. A positive experience in school is more likely to motivate lifelong learning and so create citizens keen to learn more and keen to apply their learning.

One obvious benefit for the classroom is the use of the Internet and the range of materials that are freely available to support teacher learning as well as materials for use in the classroom. Sources, such as www.youtube.com/education or www.diffusion.ens.fr, among other websites, offer materials to support teacher training. Many of the science museums of the world have websites that offer support in developing both scientific processes and science knowledge and understanding, for example www.exploratorium.edu/ or www.cite-sciences.fr. Often such sites offer the possibility to consult a scientist about students' or teachers' difficulties to meet inevitable challenges in the classroom (e.g., http://askascientist.org/). Such facilities are particularly important when dealing with the science of everyday life and how scientific ideas apply in different circumstances. For the non-expert, which includes most teachers, faced with the rapidly expanding knowledge of science, the issue is usually deciding which scientific ideas to use to explain everyday phenomena. Once the appropriate ideas are made clear, understanding becomes much easier.

Quality basic science requires quality resources both for teachers and for students. In many countries, educational research is producing materials financed by governments and there is a

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[2] Schreiner and Sjøberg 2004 – see references

[3] Schreiner and Sjøberg 2004, p9

growing trend for such materials to be freely available on the internet. This provides some degree of assurance that materials have been tried and tested and it is left to the teacher to adapt them to their context. This adaptation provides challenges for science teacher education, which must prepare teachers to make such changes.

5 Synthesis of discussion papers

In the first eight months of the project WP6 partners were active in the identification of 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 the capacity to construct their own knowledge and create their own understandings and meanings. The dow of the 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.

Motivation and engagement with one's own learning process have been recognized as cornerstones of successful education; they act as a gate to lifelong learning by favouring ownership and understanding of the learning experience and commitment to engage in further learning. Motivation is linked to a sense of protagonism in the learning experience and thus requires strategies able to understand and fruitfully build around the life-wide learning background of the learners, taking into account how this affects stimulus, attention, and construction of meaning for different learning groups. In this context, the following trends need to be considered:

- **Personalization instead of standardization of learning:** Individuals are motivated to engage with learning, when the "what" and the "how" they learn are coherent with their interests, preferences and aptitudes and recognising their personal background (including what they already know!). Personalization of paths and individualization of strategies are key to foster intrinsic motivation and ensure engagement with the learning experience. ICT offers innovative content and attractive solutions to individuals to learn what they desire at their own pace. Personalization is now gaining space also in formal learning sectors, thanks to increased modularization of paths and learner-centred approaches.

- **Integrating the learning contexts of individuals:** learning systems are increasingly acknowledging the importance, for motivation, of integrated learning paths which are nurtured by the life-wide learning experience of the learner. Continuity in learning produces meaning and develops the identity of the individual as a lifelong learner. It overcomes the fragmentation of experience, favours self-reflection and metacognition and supports the continuity between life and education, stimulating further engagement in learning.
- **Personalized assessment supporting awareness and motivation in learning:** Assessment is crucial to stimulate motivation. With learning becoming more individualized and self-managed, evaluation supports awareness of the entirety of the individual learning experience and orients the learner towards the most adequate formal, non-formal and informal learning opportunities to pursue individual goals. Changing assessment from an intimidating experience to a learning-supportive process is a core requirement of future education."

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 methods 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. 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 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. 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. Nine main science inquiry processes supported by different computer environments have been identified: orienting and asking questions; generating hypotheses; planning; investigating; analysing and interpreting; exploring and creating models; evaluating and concluding; communicating; predicting. 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 shows students the excitement and challenge of doing science and this will

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

encourage them to choose science studies in the future. To enhance the aspect further the design of the proposed activities will include interactive career counselling approaches in order to increase awareness of the value of studying science among students by demonstrating potential career opportunities.[5]

When education increases its focus on individual autonomy, meta-cognition and critical thinking, the role of teachers is expected to shift from transmitting knowledge to facilitating individual and reflective approaches to learning and knowledge building. Less standardization in teaching is required. Key teacher competences include the capacity to articulate the teaching/learning process in all its phases (identification of needs, design and implementation, evaluation) adapting it to individual and group needs.

The orchestrating role of teachers includes the definition of original and personalized learning contexts which respond to differentiated learning needs and paces, and fully profit of the opportunities offered by ICT. Digital competences (and their continuous update) are obviously essential to make this possible and increasingly affect also the capacity to produce, share and remix Education Resources.

The shift towards increased learner-centred approaches in education requires teacher to be able to fully build on and value the life-wide learning experience of students, being able to understand and master the continuum between learning contexts. The "playing field" of formal education - including school - is getting broader and requires teachers to develop competences to bridge the gap between the "in and out" of formal education. In the case of science education, the capacity to use and integrate external opportunities, such as science labs, science centres and museums, outdoor learning experiences is fundamental.

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.

Some outstanding initiatives are happening in science classrooms today. But they are only taking place because devoted, extraordinary teachers do what needs to be done despite the conventional practice. These teachers move over and above the official vocabulary-dense textbooks and encourage student inquiry-based thinking and participation. They also make their courses relevant to students' lives, instead of simply being preparation for another school science course. The aim within the participating schools is to highlight and promote the best practices of these extraordinary teachers and give them the recognition and support they deserve. If we want a powerful and innovative culture in schools that is self-sustaining, we have to empower system-aware practitioners to create it, whilst avoiding simply creating interesting but isolated pockets of experimentation. We have to instil a design based approach of

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

collaborative learning and inquiry between professional practitioners, thus creating a “pull” rather than “push” approach.[6]

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

Web 2.0 has played a key role in transforming the way people learn outside formal education, moving from transmission models (those of early distance learning) to collaborative processes and peer learning. Formal education is more resistant to abandon traditional models within which the teacher is the one who structures knowledge and the classroom is the centre of the educational process. In school, examples already exist of the smart introduction of ICT to support more personalized learning processes, able on the one hand to foster creativity and individual talents of pupils while supporting socialization and education for active citizenship. In general, ICT favours the autonomy of the individual in integrating the learning input received from the education system, enabling the learner to autonomously correct existing rigidity in the aims and boundaries of each learning cycle to adapt them to individual needs and long-term goals. ICT can be adopted in education to support the development of transversal competences and metacognition processes.

New ICT devices and services - such as apps, tablets, and smartphones - are already used in an experimental way in education to support active learning processes based on contextualization. If used in a smart way, they can favour metacognition processes and stimulate competence development by requiring an active engagement of the learner with knowledge elaboration tasks and problem solving - also through collaborative processes. Likewise, ICT can help increase the reflective practices of learners. New data tracking systems permit to record and map individual learning (i.e. e-portfolio and personal learning environment). Increasingly interoperable systems support the creation of meaningful individual paths and profiles across learning contexts, favouring meta-cognition and ownership of the learning processes. The disruptive power of ICT is that they offer access to a variety of contents, opening up a learning process which was once confined to the classroom and structured by the teacher. Problems do however arise with respect to the quality of resources and the information literacy of learners. An effort of education systems is required to support the development of necessary competences to be spent from school up to learning at work.

ICT acts itself as a powerful driver of change in the teaching process and it may help individuals to develop more learner-centred experiences and – in parallel – to support the development of new scaffolding models which are adequate to ensure – in each sector - the right balance between learner autonomy and support in learning.

From the point of view of the individual, ICT has an emancipatory power on the learner who can autonomously build his/her own learning path and adapt it to his/her pace of learning. From the point of view of the teacher, ICT allows them to orchestrate complex learning experiences which are built around the learner and their life-wide learning continuum. For sure a challenge still to be faced is the resistance of most teachers to adopt ICT, linked to the limited availability of up-to-date enabling infrastructure and adequate training especially in formal learning sectors. ICT can play a key role in stimulating and maintaining motivation to learn, by offering the possibility

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

to build individualized and contextualized learning paths – seconding learning paces and preferences - as well as to reflect and maintain control over the learning process.

This supports sense-making of what is learned and motivation to engage in further learning, by positioning the individual at the centre of his/her life-wide learning experience. Augmented reality, mobile learning, game-based learning and simulation permit to implement learning strategies based on contextualization which put knowledge in context, hereby enhancing meaning and sense of what is learned. Likewise, new workplace learning services such as "work integrated learning" and "targeted learning" favours the development of competences in context but valuing individual background in continuity with personal learning interests and increasing integration of formal and informal learning. However - ICT may also have a disruptive effect on motivation towards more traditional forms of learning which are obliged to rethink the way they stimulate engagement and investment of individuals.

ICT offers a set of instruments to support innovative approaches to assessment: to evaluate the life-wide experience of the individual and coherent with the new and multiple ways of learning enjoyed in diverse life contexts. Instruments such as the e-portfolio or learning records enable the collection of objective evidence of scattered learning experiences and meanwhile to stimulate reflection and awareness on one's own learning process and its outcomes and give it coherence and meaning. Likewise ICT can support social assessment approaches which can contribute to make informal learning explicit and give it a socially recognized value which can be spent in other contexts, including the formal ones. Within the learning process, ICT can offer instruments in the hand of both the teacher and the individual to support an iterative process of integrated assessment with a formative purpose (through for instance learning analytics or Just In Time assessment, social media).

ICT can support professional development of teachers by favouring the acquisition and consolidation of the necessary digital competences on their part but above all by supporting community of practices and exchange among teachers. The rise of peer learning and teacher networking fostered by ICT are affecting traditional institution of teacher education and particularly continuous training, which has more difficulty in being constantly updated. These are likely to be increasingly complemented by horizontal and networked teacher learning practices, favouring reflective attitudes and personally defined improvement plans.[7]

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 students, need to be motivated to do so and also to be further informed and/or educated about the educational benefits of this

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

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. Others do not feel confident enough or motivated enough 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 practice.

Below are listed and discussed various ideas and concepts that may develop into a concrete motivation scheme within the official educational system or be 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.

<u>Quantify educational benefits</u>

The majority of science teachers went through a demanding mathematical curriculum during their university studies and so 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 effectiveness and improvement of conceptual understanding when they use online labs

[3][4]. This will not only convince but also motivate teachers to at least learn about and try to adopt them simply because they will be 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.

Offer intangible rewards

All people like to be rewarded in recognition of their value, devotion, talent, expertise etc. In this regard an acknowledgement of accomplishments by peers or co-teachers or educational authorities or professional unions, associations and societies at local, national or even international level can be one of the most significant means of motivation. In practice this can 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 on the development of educational scenarios or activities using online labs along a general 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 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 money 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 are motivated to participate not only 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.

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 [2]. 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 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 high achievers' interest, enthusiasm and 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 [5].

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. 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 both.

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 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 and empowerment of the student
- Base your methodologies on significant 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
- 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

5.3.1 Understanding of the lifelong learning continuum

As the European Council Resolution stated [8]: "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".

What has to be underlined clearly and strongly, is that in principle – and in the specific fieeld of science education - we cannot take for granted that formal learning is synonymous with quality assurance and non-formal and informal learning, since less structured and not so controlled, are not. On the contrary that formal educational system is so structured and rigid that it can be seen as repressive, too costly, generally cognitive and not able to support people's attitudes to becoming active life-long learners.

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

We can find excellent examples of valuable learning experiences in all three formats (formal, non-formal and informal learning).

In contrast, we can find people who perceive their past formal background as a disastrous experience and they see themselves as failed learners. Alternatively we can find informal and non-formal learning situations in which quality and the positive results depend on variables which are not predefined and/or stable.

It can be underlined that procedures and methods to design, assure, control and assess the quality of learning and teaching experiences in formal settings have been considered relevant in the policy agenda at European level. Less awareness and effort have been given to introduce and assure quality approaches and tools in non-formal and informal learning sectors.

If we look at the three learning formats of we can identify different elements/characteristics.

Some learning activities may be perceived as belonging exclusively to one format, but they also may share aspects of the others.

In other words, each characteristic belongs to a continuum in which the effort to define it within a specific format is more related to the need of labelling or classifying than to read the real and concrete way the learning experiences are taking place.

There is a lot “informal” in the formal setting and vice versa there is a lot “formal” in informal and non formal learning experiences.

The key issue involves how all three learning formats can be integrated and seen as a means of providing a unique path/strategy for individual-personal/organisational/societal development. The success element is determined by the way each learning format can communicate and dialogue with the others, how informal-and non-formal can be integrated in formal learning and how they can serve and benefit the others. In the field of science education, the capacity to connect learning that cannot take place out of 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 different learning strategies

Education needs to wake up learners’ attention by means of their positive emotional feeling and to encourage student’s interest in science and technology.

Teachers should be creative, motivated and design methods to increase the interest of the 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. In this way, the students can experience a wide repertoire of learning practices and strategies to learn, including those that result more engaging and motivating.[9]

It is important 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.

The shift towards increased learner-centred approaches in education requires teacher to be able to fully build on and value the life-wide learning experience of students, being able to understand and master the continuum between learning contexts. The “playing field” of formal

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

education - including school - is getting broader and requires teachers to develop competences to bridge the gap between the “in and out” of formal education. In the case of science education, the capacity to use and integrate external opportunities such as science labs, science centres and museums, outdoor learning experiences is fundamental.

Collaborative, informal and peer learning are increasingly widespread practices in the teaching community. ICT offers teachers the opportunity to share ideas and resources in social communities, find learning resources online as well as opportunities for their own professional development. Experimentations and innovations in teaching are already increasingly capitalized through teacher networking.[10]

5.3.3 Understanding of the importance of planning

It seems a truism, but it should be clear that planning is a fundamental moment of classroom teaching process. We cannot imagine that an engineer or 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 very 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.

Planning it is fundamental to organize and conduct the learning processes necessary to achieve educational goals.

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 your 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 situations 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);
- Unifies criteria for greater coherence in the efforts of teaching within institutions;
- Ensures efficient use of time;
- Coordinates the participation of all stakeholders in the educational process;
- Combines different teaching strategies focused on the daily (group activities, case teaching, problem-based learning, debates, projects) for students to make connections that give meaning to their learning.

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

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.

It is most effective to use a variety of assessment and evaluation techniques. The techniques selected will depend upon students' learning styles, the curriculum objectives and the intended purpose of the assessment. Students must be given opportunities to demonstrate the extent of their knowledge, abilities and attitudes in a variety of ways. In this respect there are some crucial elements when assessing the planning process:

- It is important for teachers to communicate assessment and evaluation plans and criteria to students in advance, informing the students of the objectives to be assessed and assessment procedures to be used. Whenever possible and appropriate, students should have opportunities to input into developing the assessment criteria.
- Assessment and evaluation should be fair and equitable, demonstrating sensitivity to student, family, school and community situations. Techniques and tools should be sensitive to cultural and gender requirements, and be free of bias.
- Assessment and evaluation should help students. They should provide positive feedback and encourage students to participate actively in their own assessment in order to foster lifelong learning and enable students to transfer knowledge and abilities to their life experiences.
- Assessment and evaluation data should be communicated to students and parents/ guardians regularly, in a variety of meaningful ways (e.g., descriptive written comments, portfolio samples, parent-teacher interviews).
- Using a variety of techniques and tools, teachers collect assessment information about students' development as learners. The data gathered during assessment becomes the basis for an evaluation. Comparing assessment and evaluation information to curriculum objectives allows teachers to make decisions about further instructional requirements.

Through making explicit the planning what we intend to carry out in the classroom, although we work in a high quality way and although we intend to cover all aspects, many times this work hardly reflects the richness 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 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.

<u>Categorisations of barriers</u>

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

1. <u>Extrinsic vs. intrinsic barriers</u>

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. <u>Material vs. non-material barriers</u>

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. <u>Micro, meso, and macro level barriers</u>

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[11].

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 financial 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[12]. 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[13]. 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

[11] Bingimlas, 2009 – see list of references
[12] Bingimlas, 2009; Gahala, 2001; Bakia et al., 2011
[13] Gahala, 2001

criteria has to be developed based on national and state educational standards[14]. In conjunction with the ICT use, new learning programs 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 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[15].

5. Communication and motivation

In order to successfully implement new educational technologies at schools, communication between several target groups has to be assured[16]. 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 software 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 or a notebook to be used at home in order to better prepare to the lessons. Finally, students have to be motivated to use new tools (e.g. with assessment for completing practical parts of the courses).

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 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 hard drive[17].

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

[14] Gahala, 2001
[15] Bingimlas, 2009; Gahala, 2001; Joseph, 2013
[16] Bakia et al., 2011
[17] Schanda et al., 2012

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 goals 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 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, difficult to understand or 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. Internet access was one of the technical problems repeatedly mentioned by the teachers reporting difficulties primarily with 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 it. A problem 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 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 Lapland 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", 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 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) and recent studies (such as "Learning from Extremes" from Cisco) 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 needed but is urgent, as stated in the Learnovation Vision Paper on School Education. 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 and 'flexicurity'.

A specific discourse has to be made about ICT. A 2011 OECD (Organisation for Economic Co-operation and Development) Study 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, of 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.

When discussing how school education should evolve, priority of consideration must be given to four well identified "engines of change":

- Key competences for lifelong learning should become a pillar of school education achievements, and in particular the learning to learn competence should be a main focus of efforts.
- The use of ICT to support learning processes and to integrate the informal learning of digital natives should become an integral part of school education, considering the specific value of ICT in supporting the acquisition of key competences and learning/working processes.
- Creativity and innovation attitudes and skills are not an optional element of school education since Europe will lose its weight in global economic development without a strong innovation in its economic and social development.
- Inter-cultural learning skills are a key requirement of future citizens, workers, entrepreneurs, and will not be developed in a generalised and equitable way without a core contribution of school education.

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, 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 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 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.

In most of the widely acknowledged papers and research work, the impact of ICT on the learning processes consists in significant changes as regards the role (job) of the teacher, asking for increased competence to cater for strategic thinking, motivation and leadership and collaborative-communication potential, in order to provide mentoring in new forms of learning experiences for the students, colleagues and parents. In this evolutionary context, the consolidation of "good practice" looks for a bottom-up approach to setting the grassroots for new school learning innovations and, at the same time, for an effective approach to holistic policy-making, in order to reach the right balance with top-down planning, thus meeting the challenges for emerging paradigms concerning access to learning (the once "infrastructure-equipment" mandate), the creation and sharing of knowledge" (the once "learning materials" availability) and the building of competences in learning communities (the teachers professional development quest).

From the extended review of the ICT-for-learning policies and activities in the EU, it seems that those countries that are running a rather decentralized school system, whereby autonomy in decision-making concerning the curriculum, school program, equipping, etc., is being sustained, as it is in the case of the Nordic countries, the UK and the Netherlands, those countries show a comparatively better performance.

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:

- Information management
- Collaboration
- Communication and sharing
- Creation of content & knowledge
- Ethics & Responsibility
- Evaluation & Problem solving
- Technical operations.

Information management

Information management refers to the knowledge, skills and attitudes needed to identify, locate, access, retrieve, store and organize information.

Collaboration

Collaboration refers to the knowledge, skills and attitudes for linking with other users, participate in networks and online communities, and interact with others constructively and with a sense of responsibility.

Communication and sharing

Communication refers to the knowledge, skills and attitudes for communicating through online tools, taking into account privacy, safety and netiquette.

Creation of content & knowledge

Creation of content and knowledge refers to the expression of creativity and the construction of new knowledge through technology and media, and also to the integration and re-elaboration of previous knowledge and content and its dissemination through online means.

Ethics & Responsibility

Ethics and responsibility is understood as the knowledge, attitudes and skills needed to behave in an ethical and responsible way, aware of legal frames

Evaluation & Problem solving

Evaluation and Problem-solving is understood in more than one case study as the identification of the right technology and or media to solve the identified problem or to complete a task and also as the assessment of information retrieved or the media product consulted.

Technical operations

Technical operation is the area that refers to the knowledge, skills and attitudes one needs for effective, efficient, safe and correct use of technology and media.

Information and communication technology cannot be limited merely to Information Technology that is computers and use of the Internet. It includes everything that teachers and students make use of during the teaching/learning process. Pedagogical practice is only innovative when a teacher uses resources, materials, methods, principles and explanations (the list could go on) that have not been employed before.

Therefore, the employment of technical resources is not necessarily a satisfactory condition for innovative practice - it can serve only to support, assist or elicit innovation. This view was expressed more sharply by another colleague: *"Innovative pedagogical practice that makes use of ICT is not the same thing as using ICT in education"*. In light of this, the technical resource itself may not even be present in the given educational institution. *"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".

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, t*he 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 also include materials offered freely and openly to use and adapt for teaching, learning, development and research. While OERs are mainly shareable in digital formats (both online and via offline formats such as DVD or CD-ROM), it is important to expand the definition and also include printable formats.

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. These environments might constitute an alternative to traditional classroom teaching by promoting greater student-content interaction, and by providing students with more frequent feedback on their performance and understanding. 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.

Increasing the educational offer by facilitating the access to education resources at all levels can also have an influence on the behaviour of young people and their families, and lead to higher rates of completion of upper secondary qualifications. According to a communication titled *"Tackling early school leaving: A key contribution to the Europe 2020 Agenda"*[18] 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 offer opportunities to enhance the articulation between theory and practice, and to support teachers more effectively in becoming reflective practitioners.

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)

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

- 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. Investing up-front time finding an OER to reuse rather than starting development of new educational resources right away can save significant time and effort. OERs provide source material to build your development efforts around so there is no need to invest development effort in creating something that already exists. Finding the appropriate OER to fit 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* 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 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[19] 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)[20] portal which has been developed by European Schoolnet (EUN)[21]. LRE is a service that enables schools to find educational content from many different countries and providers. It was developed in order to provide Ministries of Education with access to a network of learning content repositories and associated tools that allow them to more easily exchange high quality learning resources that 'travel well' and can be used by teachers in different countries. The evolution of the LRE has been supported by Ministries of Education in Europe and a number of European Commission funded projects such as ASPECT[22], CELEBRATE[23], CALIBRATE[24] and MELT[25]. It is now being carried forward in projects such as eQNet[26] and with support from the LRE's content partners.

The ODS (Open Discovery Space)[27] project, is also an excellent source of OERs since it provides an integrated access point for eLearning resources from dispersed educational repositories while it engages stakeholders in the production of meaningful educational activities. To do so, it uses a social-network style multilingual portal, offering eLearning resources as well as services for the production of educational activities.

5.5.6 Institutions that encourage and support the use of education resources

In its first decade (2001-2010) the OER movement has been carried by numerous relevant and successful projects around the globe. Some of them were large-scale but the majority not, and they were primarily initiated by innovating educational institutions and explorative individual experts (i.e. MIT Open courseware[28], FLOSS project[29]). What has remained, however, is the quest for a sustainable perspective, in spite of the many attempts in the OER community for clear-cut solutions to the problem of sustainability. This remains at the top of the list of obstacles than prevent the mainstreaming of the OER approach in national educational systems.

At the end of the first decade and at the beginning of the second decade (2011-2020), we are witnessing in a few countries emerging efforts to develop and establish a national OER

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19 http://www.scientix.eu/
20 http://lreforschools.eun.org/
21 http://www.eun.org/
22 http://www.aspect-project.net/
23 http://celebrate.eun.org/
24 http://calibrate.eun.org/
25 http://info.melt-project.eu/ww/en/pub/melt_project/welcome.htm
26 http://www.eqnet.eun.org/
27 http://www.opendiscoveryspace.eu/
28 http://ocw.mit.edu/index.htm
29 http://www.flossworld.org/

approach (i.e. the National E-content and Curriculum Initiative[30] in India and Wikiwijs Program[31] in the Netherlands). Such efforts are imperative in order to break down the barriers for mainstreaming OER. Making the OER approach sustainable 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*[32] 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:

- Reinforce the development of strategies and policies on the use of education resources. Promote the development of specific policies for the production and use of OER within wider strategies for advancing education.
- Facilitate the finding, retrieving and sharing of education resources. Encourage the development of user-friendly tools to locate and retrieve OER that are specific and relevant to particular needs. Adopt appropriate open standards to ensure interoperability and to facilitate the use of OER in diverse media.
- Encourage educators and learners to actively participate in the open education movement. Creating and using open resources should be considered an integral part of education and should be supported accordingly.
- Promote the understanding and use of open licensing frameworks. Open education resources should be freely shared through open licenses which facilitate use, revision, translation, improvement and sharing by anyone. Resources should be published in formats that facilitate both use and editing. At the same time open sharing will help institutions to keep good records of materials and their internal and external use.

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30 http://poerup.referata.com/wiki/India#National_OER_initiatives

31 http://www.wikiwijs.nl/

32 http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/CI/CI/pdf/Events/Paris%20OER%20Declaration_01.pdf

- Governments, school boards, colleges and universities should make open education a high priority.

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.

6 Inputs 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

In the past two decades, a consensus has emerged on the fact that science should be a compulsory school subject. However, whilst there is agreement that an education in science is important for all school students, there has been little debate about its nature and structure. Rather, curricula have simply evolved from pre-existing forms. Such curricula mostly focus on the foundational knowledge of the three natural sciences – biology, chemistry and physics. However, such an education does not meet the needs of the majority of students who require a broad overview of the major ideas that science offers, how it produces reliable knowledge and the limits to certainty. Second, both the content and pedagogy associated with such curricula are increasingly failing to engage young people with the further study of science. The goal of science education must be, first and foremost, to develops students' understanding both of the canon of scientific knowledge and of how science functions.

All students, including future scientists, need to be educated to be critical consumers of scientific knowledge. Improving the public's ability to engage with such socio-scientific issues requires, therefore, not only a knowledge of the content of science but also a knowledge of 'how science works'. Traditional curricula in school science suffer from a number of difficulties. Knowledge is usually presented in fragmented concepts where the overarching coherence is not even glimpsed at, let alone grasped – an experience which has been described as akin to being on a train with blacked-out windows – you know you are going somewhere but only the train driver knows where. Our view is that what school science requires is a new vision of why an education in science matters that is widely shared by teachers, schools and society. Research would also suggest that deep, as opposed to superficial, understanding, comes through knowing not only that the right answer is right but also why the wrong answer is wrong. The predominant factor behind this interest is the declining numbers of young people choosing to pursue the study of science. Many countries have seen declining numbers of students choosing to pursue the study of physical sciences, engineering and mathematics at university.

Presented in this form, the experience for students is often one where:

- The science curriculum can appear as a 'catalogue' of discrete ideas, lacking coherence or relevance, with an over-emphasis on content that is often taught in isolation from the kinds of contexts that might provide essential relevance and meaning.
- The goals and purpose of science education are neither transparent nor evident to students.
- Assessment is based on exercises and tasks that rely heavily on memorisation and recall, and are quite unlike those contexts in which learners might wish to use science

knowledge or skills later in life (such as understanding media reports or having a strong basis to make personal decisions about health, diet, etc.).

- The relationship between science and technology is neither well-developed nor sufficiently explored.
- There is relatively little emphasis, within the science curriculum, on discussion or analysis of any of the scientific or environmental issues that permeate contemporary life.
- There is an over-reliance on transmission as a form of pedagogy with excessive use of copying. [33]

There is a major mismatch between opportunity and action in most education systems today. This revolves around the meaning of "Science Education", a term that is often misappropriated in the current school practice, where rather than learning how to think scientifically, students are generally being taught about science facts, rules and axioms[34]. 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. According to the recent report “Science Education in Europe: Critical Reflections”[35], the deeper problem in science education is one of fundamental purpose. Schools, the authors argue, have never provided a satisfactory education in sciences for the majority. Now the evidence is that it is failing even in its original purpose, to provide a route into science for future scientists.

The challenge therefore, is to re-imagine science education: to consider how it can be made fit for the modern world and how it can meet the needs of all students; those who will go on to work in scientific and technical subjects, and those who will not[36]. In our view the science classroom should provide more challenging, authentic and higher-order learning experiences, more opportunities for students to participate in scientific practices and tasks, using the discourse of science and working with scientific representations and tools. It should enrich and transform the students’ concepts and initial ideas, which could work either as resources or barriers to emerging ideas.

The science classroom should offer opportunities for teaching tailored to the students’ particular needs while it should provide continuous measures of competence, integral to the learning process that can help teachers work more effectively with individuals and leave a record of competence that is compelling to students. 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 publicly available, and can provide a catalyst for science learning. Schools, universities, research centres, science centres can act as mediators, organising information and knowledge across scientific disciplines and providing tools for understanding complex scientific research, making science understandable and interesting to the student. Attracting students’ attention and interest by presenting contemporary ideas and by offering activities that are closely related to

[33] Science Education in Europe: Critical reflections - a report to the Nuffield Foundation; Jonathan Osborne, Justin Dillon King’s College London
[34] Alberts, 2009 – see references
[35] Osborn & Dilon, 2008
[36] Kali & Linn, 2009

new technological achievements and everyday life is one of the keys to stimulate students and contribute to the discovery of the next generation of innovators.

This way of introducing science helps students to overcome the idea of it being complex and too difficult for them to understand and helps them to see it as a tool to explore and understand nature. Offering advanced and highly stimulating “hands-on” experiences to students that actually involve them into making observations and expressing conclusions instead of offering them occasional tours to such experiments will contribute to the development of their critical skills and competences as well as the enhancing of their ability to use scientific language. [37]

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

Inquiry based approaches to learning science incorporating students’ active investigation and experimentation are necessary to motivate students for science (e.g. Osborne & Dilon, 2008; Rocard, et al., 2007) and that, therefore, inquiry should be part of the curriculum also because inquiry skills have a value on their own (e.g., National Research Council, 2000; National Science Foundation, 2000; The National Academies, 2011). Inquiry is the process in which students are engaged in scientifically oriented questions, perform active experimentation, formulate explanations from evidence, evaluate their explanations in light of alternative explanations, and communicate and justify their proposed explanations (National Research Council, 2000). There is also overwhelming scientific evidence that inquiry leads to better acquisition of domain (conceptual) knowledge (de Jong, 2006a). 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[38].

Contemporary, Technology Enhanced Learning (TEL), approaches to science learning provide students with ample opportunities for inquiry. TEL environments that offer simulations, games, data sets, and/or remote and virtual laboratories are significant in this respect. In these environments technological affordances are directly used for pedagogical purposes in that inquiry calls for non-linear, flexible and useable content which technology is able to offer. Evidence is accumulating that TEL inquiry environments provide students with genuinely effective learning opportunities and large scale studies show that, on different outcome measures, TEL-based inquiry outperforms more direct approaches to instruction[39]. These promising results, however, only hold when the inquiry process is structured and scaffolded. Scaffolds thus play a pivotal role in inquiry learning. Scaffolds come in many kinds. Examples are tools to create hypothesis, data analysis tools, and tools to save and monitor experiments.

Currently a growing number of TEL inquiry environments have emerged that provide students with inquiry facilities together with integrated supportive structure and scaffolds. Examples of such learning environments are: Smithtown[40]; Belvedere[41]; BGuILE[42]; BioWorld[43]; Inquiry Island

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

[38] Minner, Levy, & Century, 2010

[39] Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Deslauriers & Wieman, 2011; Eysink et al., 2009; Marusic & Slisko, 2012; Scalise et al.,2011; Smetana & Bell, 2012

[40] Shute & Glaser, 1990

(White et al., 2002); GenScope ([44]); SimQuest-based environments (de Jong et al., 1998); Co-Lab[45]; WISE (Linn, Davis, & Bell, 2004); STOCHASMOS[46] (); and SCY (de Jong et al., 2010). All these environments are based on simulations and/or remote labs.

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. Basic science literacy, coupled with scientific competencies and skills – namely drawing conclusions based on observation, experiment and analysis – provides citizens with the tools needed for rational debate and sound decision-making based on scientific knowledge.

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.

OECD has carefully reviewed the literature and has made a valuable effort in clarifying the concept (OECD, 2006*b*). Accordingly, PISA 2006 refers to *scientific literacy* as an individual's:

- 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.

Scientific literacy is the outcome of quality science education. Research in a range of countries has clearly shown a positive correlation between high scientific literacy and the level of general education attained[47]. Formal education can provide basic scientific literacy for students in preparing for the workplace. However, science education in schools can hardly satisfy the needs of the general public towards improvement of their scientific literacy. Both informal and non-formal science education are also essential components of lifelong learning. Furthermore, widespread scientific literacy is also a vital element in gaining public support for continuing advances in scientific disciplines.

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[41] Suthers, Weiner, Connelly, &Paolucci,1995
[42] Reiser et al., 2001
[43] Lajoie, Lavigne, Guerrera, & Munsie, 2001
[44] Hickey, Kindfield, Horwitz, & Christie, 2003; Hickey & Zuiker, 2003
[45] van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005
[46] Kyza, Constantinou & Spanoudis, 2011
[47] CAST, 2004; Miller, 2002; Pardo & Calvo, 2004; Shukla *et al.* 2005

Science education involves multiple levels and modes of education. Education occurs both inside and outside the classroom. Formal education is generally provided at primary (up to 10-12 years of age), secondary (12-18 years of age) and tertiary (college and university) levels, while informal education occurs outside the classroom in a variety of settings, and can be a life-long continuing learning process.

There are enormous variations in the quality of schools, from very well equipped establishments to those that may not even have a proper classroom - laboratories for its students. While this divide is more glaring between urban and rural schools, even in urban areas schools with very limited facilities exist.

In addition to education in formal settings, scientific disciplines need to be taught and learned through informal education settings, out of school: in homes, communities, museums, botanical gardens, aquariums, zoos, for all ages and for life-long learning[48]. With increasingly ubiquitous technological access, the geographical constraints on learning are disappearing through the use of information networks, on line tools and labs, mobile media and social networks. The importance of the 'informal' education sector (curiosity-driven education outside the formal classroom in many venues and from many sources – museums, science centres, field experiences, camps or at home, as well as media communications) has been well documented in recent years (NRC, 2009). With the increasing need for informing the general public about scientific and technological matters, and the concern of the science community over public support, there is an obvious need to improve the informal science learning environment.

There is a need to upgrade teachers' capabilities in most countries, especially with regard to content and pedagogy, and in facilitating hands-on activities for science lessons, as well as on the introduction of contemporary technologies to enhance student learning in science. The situation is particularly pressing with respect to teachers at primary and secondary school levels. It is here that the foundations for an enquiring mind and of basic concepts are laid. Many teachers at these levels are ill-informed about current developments in science, and, being themselves frustrated due to poor working, economic or social conditions, they can hardly be expected to provide inspiring mentorship.

The state of science education at the tertiary or post-school level is also less than satisfactory in many parts of the world, and especially so in the developing countries. The causes are rooted primarily in the lack of competent and motivated teachers, the lack of laboratory facilities and outdated course contents. Under such conditions, much of the learning of science is reduced to memorization exercises to let the students somehow qualify for a degree.

Teachers' pedagogical and subject knowledge is critical to effective teaching. Unfortunately, in most countries around the globe, teacher preparation in science and mathematics is inadequate. There is an urgent need for better training of teachers at all levels in order that they can not only provide accurate information to their students, but also do it in a manner that triggers their imagination and fosters curious and analytical minds. Since the service conditions for teachers remain very poor in most countries, an important component of any effort to improve science education is the need to improve the prestige and attractiveness of the

[48] NRC, 2009; Stevens & Bransford, 2007

teaching profession, such that talented individuals are attracted to the profession and are able to share their knowledge and enthusiasm with students. Learning and teaching are inseparable. Continuous learning by teachers is essential, especially in view of the dynamically changing concepts and information in different branches of science. Therefore, continuous high-quality professional development of teachers is essential for good educational outcomes for their students. Programs for the effective professional development of teachers typically include one or more of the following activities.

- 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.

A remarkable opportunity for global science education is provided by the Internet, one of the most important sources of information worldwide, for learners and educators alike. Many excellent educational resources are now available on line. Some are available as ‘Open Educational Resources’ (OER) – meaning that the resources have license terms that make re-use and re-mixing easy for the user without fee and with minimal attribution requirements. Many leading educational institutions recognize the potential of OER as a means of coping with an ever-increasing population of students with limited financial and/or human resources. A large number of portals dedicated to the sharing of science education innovations, experiences and educational materials are now available. From the point of view of both teachers and learners, the current explosion of web-based educational resources has created new challenges and limitations. First, while a variety of powerful search engines are freely available.

6.2 Other trends affecting education at large

Some other trends that are influencing education internationally are sure to have an impact on science education as well.

MOOCs: In the past year, massive open online courses (MOOCs) have attracted interest from universities and from venture capital investors. MOOC platforms have been announced from Australia to the UK, but the focus is still currently on North America. The US-based providers Coursera, Udacity and edX are exploring business models involving paid-for assessment, the award of recognized credit, and recruitment of students to campus courses. Typically, around 20,000 learners register for a MOOC, with 5-10 percent reaching the end point. In terms of pedagogy, the currently dominant approach is a transmission model involving video lectures, recommended readings and staged assessment. MOOCs are an evolving and expanding area with new developments likely to offer greater variety of courses and more innovative social learning pedagogies. They also offer the chance to run experiments that compare teaching methods.

Badges to accredit learning: Badging offers a flexible mechanism for recognizing achievements as steps towards more substantial goals. Badging can also provide an informal alternative to accreditation. During 2012, the initial infrastructure profile for badges became established. In 2013, there are encouraging signs that the tools and infrastructure are improving, with implementations appearing for mainstream learning environments. Educators are increasing their use of badging to help courses run successfully online and to motivate learners. Badging implementation requires further development, for example to offer more flexible ways to provide evidence. Lack of structures that can combine badges into a common accreditation framework currently limits their use. Greater awareness and presence of badging is needed for future advancement.

Learning analytics: Learning analytics involve the collection, analysis and reporting of large datasets relating to learners and their contexts. Current developments are focused on three areas: understanding the scope and uses of learning analytics; integrating analytics into existing courses; and expansion of learning analytics to new areas, particularly MOOCs. A central challenge is to develop analytics that are driven by key questions, rather than just querying data collected from online systems. The relation of learning design to learning analytics is also being considered, so that new teaching methods and curricula are informed by analysis of previous experience. Methods of learning analytics not only examine past interactions but also support future outcomes for students and educators. Other key issues include secure data storage, appropriate levels of access, and providing the necessary infrastructure for storing and querying large data sets.

Seamless learning: Seamless learning (connecting learning experiences across the contexts of location, time, device and social setting) is moving from research to mainstream adoption. Mobile technologies enable learners of all ages to operate across contexts, for example schools allowing students to bring their own devices. Pedagogy is emerging, based on learners starting an investigation in class, then collecting data at home or outdoors, constructing new knowledge with assistance from the software, and sharing findings in the classroom. There is also a broader notion of seamless learning arising from connected experience. Our activities online are increasingly matched to our interests: search pages order responses based on previous queries; websites recommend content related to our past viewing. The benefits are that personally relevant information may be ready to hand, but the danger is that we may come to believe that our views, preferences and connections are not just the most relevant, but all there is.

Crowd learning: Crowd learning describes the process of learning from the expertise and opinions of others, shared through online social spaces, websites, and activities. Such learning is often informal and spontaneous, and may not be recognised by the participants as a learning activity. In this model virtually anybody can be a teacher or source of knowledge, learning occurs flexibly and sporadically, can be driven by chance or specific goals, and always has direct contextual relevance to the learner. It places responsibility on individual learners to find a path through sources of knowledge and to manage the objectives of their learning. Crowd learning encourages people to be active in setting personal objectives, seeking resources, and recording achievements. It can also develop the skills needed for lifelong learning, such as self-motivation and reflection on performance. The challenge is to provide learners with ways to manage their learning and offer valuable contributions to others.

Digital scholarship: Digital scholarship refers to those changes in scholarly practice made possible by digital and networked technologies: open access publishing, open science, digital humanities, the use of social media by academics, digital and citizen science. In the information and library sciences, a focus on digital curation reflects an interest in the ability of scholars to assemble, search across and publish annotated collections of interconnected multimedia artefacts. Digital scholarship demonstrates many elements of open and networked forms of scholarship. Open-access publishing and open peer review enable sharing of knowledge. Open publishing of research datasets supports reproducible research. Engagement in open educational practices has the potential to support moves towards a more free and collegiate teaching practice.

Geo-learning: Sensors built into mobile devices, such as smartphones and tablets, can determine a user's location and provide, or trigger, context-aware educational resources in the surrounding environment. These can enable both formal and informal learning within physical 'real-world' settings. They may also enhance and frame the subject matter being studied. For example, learning about an historical event could be situated in the place where that event occurred, giving a rich sensory experience of being in the scene. Fieldwork activities have long encompassed 'geo-learning' as a way of providing information that exploits the surroundings and landscape. Geo-learning is not new, however technologies sensitive to location, or embedded in objects near the learner, now allow greater mixing of digital information with the physical world, to produce 'blended spaces'. We need to consider carefully how we employ these opportunities for learning. Current theories are somewhat limited, but several approaches, including research into learning spaces, provide ways to model the richness of these environments and our interactions within them.

Learning from gaming: There is increasing interest in the connections between games and education. When implemented as 'edutainment' or 'gamification' of learning, teaching practices can gain superficial elements of entertainment and reward. This may encourage learners to continue, however misses the power of digital games for engagement, reflection and self-regulation. New approaches of 'intrinsic integration' are linking the motivational elements of games with specific learning activities and outcomes, so that the game-play is both engaging and educationally effective. Game designers can achieve this by developing games with elements of challenge, personal control, fantasy, and curiosity that match the pedagogy. They can manipulate aspects of 'flow' (a player's feeling of absorption in the game) and strategy to produce a productive cycle of engagement and reflection. The shared endeavours, goals and practices in games also help build affinity groups gathering learners into productive and self-organizing communities.

Maker culture: Maker culture encourages informal, shared social learning focused on the construction of artefacts ranging from robots and 3D-printed models to clothing and more traditional handicrafts. Maker culture emphasizes experimentation, innovation, and the testing of theory through practical, self-directed tasks. It is characterized by playful learning and encourages both the acceptance of risk taking (learning by making mistakes) and rapid iterative development. Feedback is provided through immediate testing, personal reflection, and peer validation. Learning is supported via informal mentoring and progression through a community of practice. Its popularity has increased due to the recent proliferation of affordable computing hardware and 3D printers, and available open source software. Critics argue it is simply a rebranding of traditional hobby pursuits. Proponents contend that recent evolutions in networking technologies and hardware have enabled wider dissemination and sharing of ideas for maker learning, underpinned by a powerful pedagogy that emphasizes learning through social making.

Citizen inquiry: Citizen inquiry refers to mass participation of members of the public in structured investigations. It fuses the creative knowledge building of inquiry learning with the mass collaborative participation exemplified by citizen science, changing the consumer relationship that most people have with research to one of active engagement. The concept is that people who are not research professionals engage in collaborative, inquiry based projects. For each investigation, they gather evidence of similar successful projects, create a plan of action, carry out a controlled intervention if appropriate, collect data using desktop and mobile technologies as research tools, and validate and share findings. Citizen inquiry not only engages people in personally meaningful inquiry, it can also offer the potential to examine complex dynamic problems, such as mapping the effects of climate change, by means of thousands of people collecting and sharing local data

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, Ney, van Joolingen, and de Jong (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 and colleagues (Corter, et al., 2011; Corter et al., 2007), 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. Kong, Yeung, and Wu (2009) also report that both teachers and students show high involvement in remote laboratories.

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). Lowering fidelity means that the requirements on students are less severe which may add learning[50]. Augmenting reality means that concepts that are not visible for students in the physical laboratory now become visible[51].

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[52]. Our next exploration is how to potentially combine remote and virtual labs.

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. There are different possibilities here: blending[53] and alternating both modes for the

[49] Toth, Morrow, & Ludvico, 2009
[50] Alessi, 1988
[51] such as the flow of electric current, see e.g., Jaakkola, Nurmi, &Lehtinen, 2010
[52] Ma & Nickerson, 2006
[53] Olympiou & Zacharia, 2012; van Joolingen, et al., 2005

same[54] or different contents[55]. Blending means that characteristics of virtual labs, such as augmentations, are added to remote labs[56].

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. Example studies are Zacharia and Anderson (2003) mechanics, optics, and heat and temperature; Akpan and Andre (2000) on the dissection of a frog, Martínez-Jiménez, Pones-Pedrajas, Climent-Bellido, and Polo (2003), Zacharia (2007)on electrical circuits, Zacharia, et al. (2008) on heat and temperature, Jaakkola and Nurmi (2008) and Jaakkola, Nurmi, and Veermans (2011) on electrical circuits, and Dalgarno, Bishop, Adlong, and Bedgood Jr (2009) on a chemistry laboratory. 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 create hypotheses[57], design experiments[58], make predictions[59], formulate interpretations of the data[60], reflect upon the learning process (Davis, 2000),plan and structure their work[61], and monitor what has been done[62]. We can also scaffold the complete process by having student work with an inquiry cycle[63]. Different types of structuring and scaffolds and their effects on knowledge acquisition have been overviewed in several studies[64]. In any case meta-analyses[65] show that inquiry learning is only productive when the inquiry process is structured and scaffolded.

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[54] Jaakkola & Nurmi, 2008
[55] e.g., Zacharia, Olympiou & Papaevripidou, 2008
[56] Yueh & Sheen, 2009
[57] van Joolingen & de Jong, 1991
[58] Lin & Lehman, 1999
[59] Lewis, Stern, & Linn, 1993
[60] Edelson, Gordin, & Pea, 1999
[61] van Joolingen, et al., 2005
[62] Hulshof,Wilhelm, Beishuizen, & van Rijn, 2005
[63] Manlove, Lazonder, & de Jong, 2007
[64] Bell, Urhahne, Schanze & Ploetzner, 2010; Chang, et al., 2008; de Jong, 2006b, 2010a, 2010b; de Jong & van Joolingen, 1998; Fund, 2007; Linn, et al., 2004; Quintana et al., 2004; Sandoval & Bell, 2004; Zhang, Chen, Sun, & Reid, 2004

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[66]. In modern labs work is always done in teams and the ability to work with others is a requirement for skilful lab work[67]. 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[68]. 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.

Inquiry learning tasks allow students to express and explore their own strategies and conceptions. 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[69]. 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.

However, Emerging Learning Objects (traces) produced by students in the course of their inquiry learning activities would optionally be shared with others in the Go-Lab Portal[70]. 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

[65] Alfieri, et al., 2011
[66] Corter, et al., 2011; Feisel & Rosa, 2005
[67] Dunbar, 1999
[68] Lou, 2004; Lou, Abrami, & d'Apollonia 2001
[69] Teasley, 1997
[70] see, de Jong, et al., 2010

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.

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9 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