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How "Discover the COSMOS", "PATHWAY", "Go-Lab" and "Inspiring Science Education" are changing the science education in European high schools.

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Abstract. It has been noted by various reports that during recent years, there has been an alarming decline in young people's interest for science studies and mathematics. Since it is believed that the traditional teaching methods often fail to foster positive attitudes towards learning science, the European Commission has made intensive efforts to promote science education in schools though new methods based on the inquiry methodology of learning: questions, search and answers. This should be coupled to laboratories and hands-on experience which should be structured and scaffolded in a pedagogically meaningful way. "PATHWAY", "Discover the COSMOS" and "ISE" have been providing the lesson plans and the best practices for teachers and students and "Go-lab" is working towards an integrated set up of on-line labs for large scale use in science education. In the next sections some concrete examples which aim to bring the High Energy Physics (HEP) frontier research to schools will be given.

1 Introduction

This paper describes how four European Commission's (EC) programs called "Pathway –Inquiry Science Education" (1) and "Discover the COSMOS" (2) , "Global Online Science Labs for Inquiry Learning at School (Go-lab)" (3) and "Large Scale Experimentation Scenarios to Mainstream *eLearning* in Science, Mathematics and Technology in Primary and Secondary Schools (ISE)" (4) hope to influence the science education in schools and increase interest towards science. The first project is the only one which focuses on teachers and their effort of making science education more attractive to students, while the other three are addressed to both teachers and students. All of them aim to organize better existing resources in science and introduce the cutting edge technology to schools. Rich data bases and *eScience* infrastructures from renowned organizations such as CERN, ESA and University's robotic telescopes are made publicly available in an easily searchable way and connected to the national school curricula, in order to act as catalysts to *eLearning*.

Students and teachers get engaged in playful science learning using innovative learning tools. The basic philosophy of all the above projects is that the learning of science is a process of creating knowledge by learners. They are based on the effective use of ICT tools (virtual environments, visualization technologies, 2D and 3D animations, simulations, interactive games) in order to offer a "feel and interact" user experience, allowing for learning "anytime, anywhere". In addition, all projects propose a reversal of science teaching in school from deductive lectures to the inquiry-based approach which raises the interest and curiosity of the students. The Inquiry Based Science Education (IBSE) is effective with all kinds of students from the weakest to the most able and is fully compatible with the ambition of excellence. Moreover IBSE is beneficial to promoting girls' interest and participation in science activities. Finally, IBSE and traditional deductive approaches are not mutually exclusive and should be combined in any science classroom to accommodate different levels of knowledge, age groups and adjusted to different national teaching curricula.

2 Pathway to Inquiry based Science Education

The project was launched on January 1st 2011 and ends at the end of 2013. It involves twenty five partners from all over the world, and is coordinated by the University of Bayreuth. Following the EC recommendations of the Rocard report: "Science Education Now: A renewed Pedagogy for the Future of Europe" (5) , the project brings together partners from the field of science education research, or scientists and researchers involved in pioneering scientific research, as well as, policy makers and curriculum developers. This blend of different expertise shown in Figure 1 aims to promote the effective widespread use of IBSE techniques in primary and secondary schools in Europe and beyond; in addition it facilitates the development of communities of practitioners of inquiry that will enable teachers to learn from each other and diffuse their skills to other teachers.

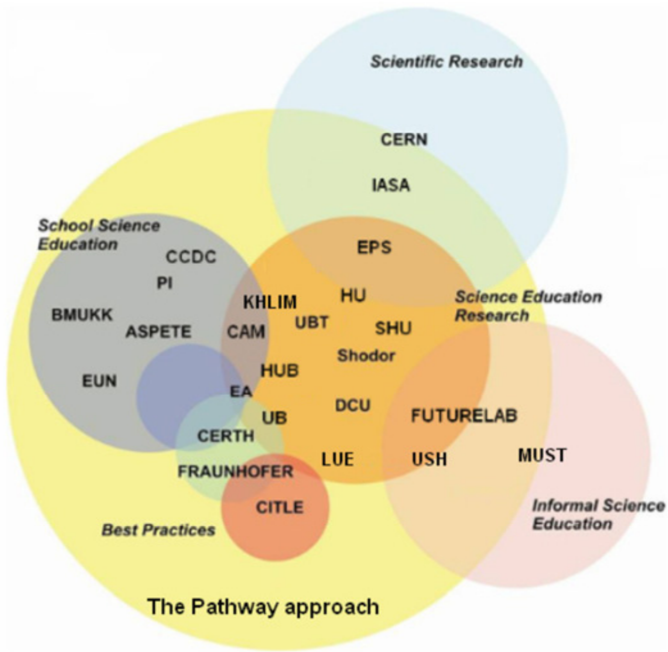

Figure 1. The members of the PATHWAY consortium and the relevant areas of expertise covered in the framework of the work elaborated by the project.

So far the project has, after its first year of operation, delivered a set of *guidelines for the educational community* to further explore and exploit the unique benefits of the proposed approach in science teaching. These guidelines are publicly available (6), in ten different languages. The document helps prepare the teacher for the Inquiry-Based teaching by reviewing the necessary techniques in order for him/her to become skilled in the method. Furthermore it gives concrete examples of the application of the method in schools and thus provides a guide, a roadmap for the implementation of IBSE in teachers' everyday practice, even for teachers who have no experience in the design of such methods. In addition, the guide gives detailed instructions and examples on how to do so using standard tools based on IMS learning Design (7) and developed by the project. The tool enables the community members to design scenaria of their own as well, based on best teaching practices.

The consortium has also presented a series of "success stories" from topics which are of interest to the students and relevant to their lives. The Best Practices developed have multiple goals. They aim to develop:

- Understanding of a set of big ideas in science which includes ideas of science and ideas about science and its role in society
- Scientific capabilities concerned with gathering and using evidence
- Scientific attitudes

The Pathway Best Practices are organized in four main categories:

- School-Based Educational Activities based on IBSE. Fourteen scenaria from primary school applications to F1 application in schools. Figure 2 shows students working on the latter scenario.

Figure 2. Students aged 9-19 use CAD/CAM software to design, analyze, manufacture, test and race their miniature F1 cars made of balsa wood and powered by compressed air cylinders.

- Educational Activities that promote school – science centre and museum collaboration (ten scenaria; one such example is the integrative science education courses at HEUREKA- the Finnish Science centre)
- Educational Activities that promote school – research centre collaboration (ten scenaria; several activities have to do with research at CERN and particle physics which will be described in the next session or astronomy or UnischoolLabs (8))
- Educational Activities connecting Formal and Informal Learning settings (like exploring the OpenScienceResources (9) towards the development of a shared digital laboratory)

The implementation of the Best Practice by as many teachers and schools as possible is a clear progression towards the goals of IBSE. Extensive training sessions during the first two year life of the project took place in communities in Germany, Austria, United Kingdom, Ireland, Spain, Italy, Greece, Finland, France, Netherlands, Belgium, Israel, Switzerland, Bulgaria, Romania and Russia in order to act as the pilot group for the project activities. The trained teachers then practiced the mastered techniques of inquiry and acted as change agents in their schools facilitating the implementation and further diffusion of inquiry based methods in teaching practice. The sustainability of the approach is guaranteed by the gradual development of the community of teachers – change leaders (first locally, and then gradually nationally and finally at the cross-European level).

The project is been systematically validated by the European Schoolnet (EUN) (10), the network of thirty one European Ministries of Education. EUN has long experience in validating innovative approaches to teaching and learning. In this framework EUN mobilized the necessary number of validation experts in the participating countries, developed the optimum validation schemes for such a large scale initiative and used as validators a large network of users. Up to now 5,000 teachers out of the final goal of 8,500 teachers, have been trained in specialized workshops.

3 The Discover the COSMOS project

The “Discover the COSMOS” project started on 1st September 2011 and ended at the end of August 2013. It belonged to EC’s coordination actions, was coordinated by the author of this article and involved fifteen partners from Europe and US, experts in the fields of astronomy, particle and space physics (11) as well as in the field of science education research.

Discover the COSMOS coordination action has implemented a great number of activities that interconnect schools and research centers following a detailed pedagogical framework. The Discover the COSMOS activities introduced students to concepts and ideas of big science in the fields of Astronomy and High-Energy Physics. As such they safeguard sustained intellectual engagement by the majority of students, while promoting the interest of the few who will choose to pursue careers in science. In the framework of the educational activities implemented, the students were asked to employ real-problem solving skills, to handle and study situations, and to engage in meaningful and motivating science inquiry activities. The approach that Discover the COSMOS implements was to bring the use of ‘cutting-edge’ *eScience* applications to school students. Project activities such as the analysis tools for real events collected by the high-tech research infrastructures of ATLAS (12) and CMS (13) experiments at CERN and the remote real-time access to a number of telescopes were available to the students locally at their schools (mini and e-Masterclasses), triggered students’ scientific adventure and incorporated the ‘wow’ factor (i.e. wonder) in the learning of science.

More precisely, the objectives of the project were to:

- Select a series of *eScience* initiatives that successfully introduced the scientific methodology in school science education, by utilizing existing research infrastructures of frontier research institutions enriched with online tools (data analysis tools, simulators and games) and web-interactive educational material.
- Integrate these initiatives under a common educational approach and develop the *Discover the COSMOS Demonstrators* that could be exploited and widely used from the educational communities in Europe and beyond.
- Implement the *Discover the COSMOS Demonstrators* at large scale in Europe, and organize a series of raising awareness activities that introduced students and teachers to *eScience* through the use of real scientific instruments (robotic telescopes, accelerators and particle detectors).
- Create virtual learning communities of educators, students and researchers and involve them in extended episodes of playful learning.
- Systematically validate the proposed approaches and activities in order to identify their impact in terms of the effectiveness and efficiency.
- Design and implement a systematic raising awareness strategy that contributes to the effective communication of the project’s results and outcomes.

As discussed above, in the framework of the project, the Discover the COSMOS consortium has selected a series of *eScience* initiatives that offered access to large research infrastructures to act as pilot cases. At the same time the organization of these initiatives were coordinated under a common methodological approach for the design and implementation of large scale outreach activities in the school communities. Obviously the usage of these resources by teachers and students provided an innovative way to easily expand greatly the limitations of classroom instruction. The resources were then enriched with the necessary pedagogical framework (connections to the curriculum, organization at different levels of complexity, pedagogical and technical support, teachers’ training activities) in order to create a large number (over one hundred) of exemplary lesson plans the so called "*Discover the COSMOS Demonstrators*". The demonstrators can be found on the project's portal (DtC portal) (14) and are classified in a structured and searchable way according to subject (with keywords), age group, duration, degree of difficulty etc. using metadata files. The portal besides being the unique repository of the demonstrators, includes material from the "COSMOS" (15) as well as "The Learning with ATLAS@CERN" (16) portals/databases. The exemplary lesson plans were then enriched by additional lesson plans (learning activities) created by the users of the portal themselves, mainly teachers and mostly during the summer/winter schools and training sessions. Presently the portal has a repository of about 650 structured learning activities in all the consortium languages (English, French, German, Spanish, Portuguese, Greek) and beyond. It also includes over 94,000 educational objects (photos, videos, animations, exercises, graphs, links).

The Discover the COSMOS initiative has brought together key players in the field of Particle Physics (e.g. CERN in Europe and LBNL in USA) and Astronomy outreach that have invested major efforts to introduce frontier research issues into the schools' classrooms in Europe and beyond;

- the CERN High School Teachers Training Programme (17)
- the Hands On Particle Physics Masterclasses (18)
- the Galileo Teachers Training Programme (19)
- the Hands On Universe initiative (20)
- the National Schools Observatory (21)
- the SkyWatch Contest (22)

These are some indicative examples of successful initiatives that made use of large scale research infrastructures and advanced *eScience* applications.

3.1 The HEP Masterclasses

As stated above, the teachers had at their disposal several tools to interactively analyze data from the gigantic ATLAS and CMS experiments at CERN's LHC accelerator (23). LHC brings to collisions hadrons (mainly protons) with the highest energy in the world.

More structured usage of the HEP real data is done in the so-called "Masterclasses" or "e-masterclasses". In the International Masterclasses (24) each year about 10,000 high school students in thirty seven countries go to one of about 160 nearby universities or research centers for one day in order to unravel the mysteries of particle physics. Students become "researchers for a day". They follow lectures from active scientists where they learn about fundamental subatomic particles and interactions, detectors, accelerators in order to enable them to perform an active investigation, namely measurements on real data from particle physics experiments themselves. Various tools for this analysis can be found in HEP tool-box of the DtC portal. At the end of each day, like in international research collaboration, the participants join in a video conference for discussion and combination of their results.

The e-masterclasses and mini-masterclasses which were pioneered by the Discover the COSMOS project are smaller scale masterclasses where the students can stay in their own school (or go to CERN) and are guided remotely (by video-conferencing) or by a few visiting scientists and with the simultaneous help from their trained teachers, perform the measurements. A few schools can be connected at the end of the day to discuss their results as well. Usually these masterclasses are accompanied by a "virtual visit" to the ATLAS control room, the center where the data are taken. This way the students have the opportunity to see the scientists at work "doing their shifts" and discuss with them in a long question and answer session, after the presentation of the experiment. Figure 3 shows a map of the very recent masterclasses performed in Greece during the academic year 2012-2013, which covered almost all regions of the country. Two videos (25), (26) show pilot e-masterclasses with Dutch and Polish students visiting CERN and guided remotely by the author's team in Athens.

During most of the masterclasses, the analysis tool called "HYPATIA: HYbrid Pupil's Analysis Tool for Interaction in ATLAS" (27) -developed by members of the consortium and presented in this conference by Mr. S.Vourakis- was used to interactively analyze the real data from the ATLAS experiment. Figure 4 shows a screenshot of one of the exercises of the tool. The tool runs on-line and has four different levels of difficulty. Students can simply observe the products of collisions or learn to identify particles and finally “hunt” for the Higgs particle!

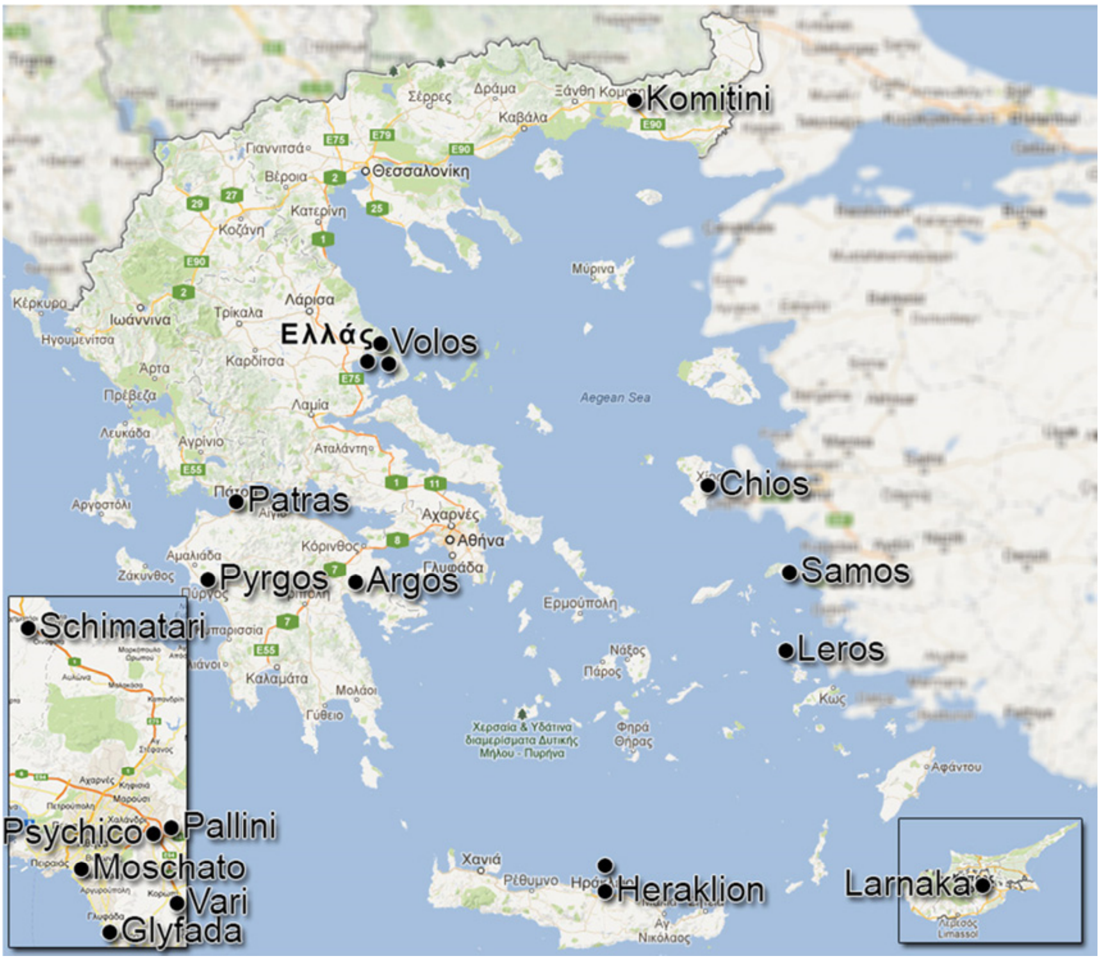

Figure 3: HEP masterclasses run in Greece and Cyprus during the academic year 2012-2013

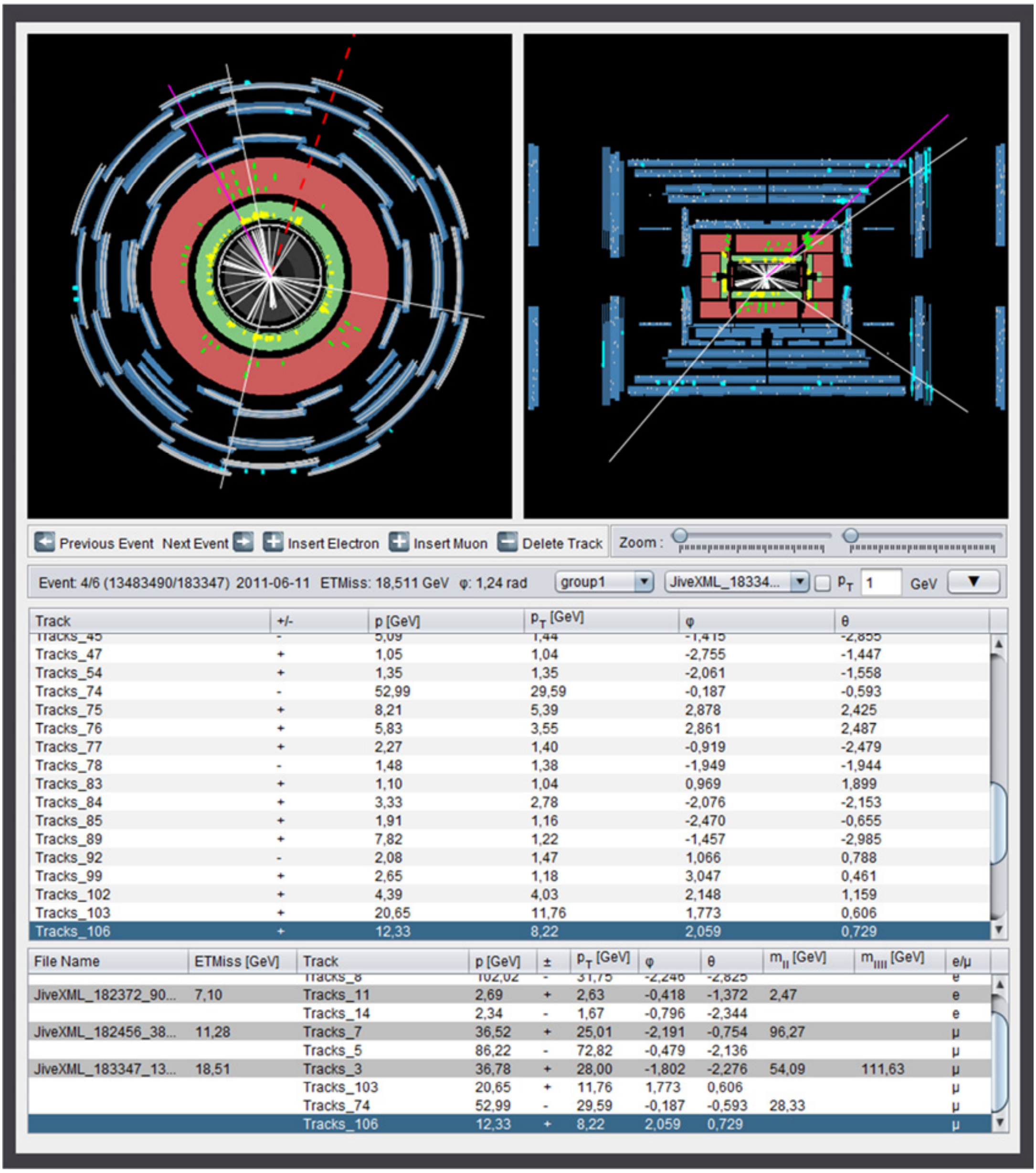

Figure 4. The “HYPATIA/applet” application for real data analysis of the ATLAS events

The repository of the DtC portal includes also two mobile phone applications which allow users to exploit both HEP (moCERN) and astronomy resources (moCo). The moCERN application which was developed by the Federal Austrian Ministry of Education (BMUKK) is shown on Figure 5.

Figure 5. The mobile phone application developed by the Austrian Ministry of Education (BMUKK) in order to exploit CERN.

On the astronomy front, the DtC portal offers access to a network of six robotic telescopes as well, in which the teacher can schedule time slots for observation. The National School's Observatory (21) established by the Liverpool John Moores University which was a partner, as well as the Faulkes (28) telescopes are available for booking observation time by the students. As an example, in January 2012, six schools from UK, Ireland, Poland, Portugal and France observed the asteroid Kariba over five hours; they 'met up' on Skype for advice and student questions, used the SalsaJ (29) software and observations to produce its lightcurve. SalsaJ (available in twenty five languages), LTImage (30) and "Sun for all" (31) are software packages developed over the years by the partners in order to analyze images, and can be found in the astronomy tool-box of the DtC portal. The "Sun for all" scientific archive alone, includes over 30.000 Sun images captured the last 80 years.

Additionally national and international contests for teachers and students, international training seminars and summer/winter schools along with teachers' training activities at large scale took place in the framework of the project to effectively support the widespread of the above activities in the participating countries and beyond.

The DtC was also presented in science fairs and festivals like the Sofia Science Fair and the CERN Open days (together with Go-lab) with a dedicated stand, workstations for hands-on experience with the projects' labs. Moreover, in a the special session of the CERN Council in Brussels on the 30th of May 2013, dedicated to the update of the European Strategy for Particle Physics, the DtC and Go-lab were presented as exemplary online labs during the accompanying events. In one of the main outcomes of the meeting, the brochure "Accelerating science and Innovation-Social benefits of European research in Particle physics" in the chapter "Society and skills" it is reported that "Discover the COSMOS and the Go-Lab projects are new way of bringing frontier physics to schools; there have been remote masterclasses for students from around the continent " (32).

Using all the variety of communication and social networking tools, a community of practitioners for transferring the pilot implementations to the real introduction of *eScience* in school settings has been scaling-up. Furthermore, in order to further enlarge the community, continuous dissemination and clustering activities took place during the whole duration of the project and will be continued after its end. Using as main vehicles the CERN outreach programme, the Global Hands On Universe initiative and the Galileo Teachers Training programme, the consortium promoted the project work at many countries beyond Europe. Only through the Galileo teachers' community (19), the consortium had access to 16,000 teachers in 100 countries including Latin America and Asia!

Finally the impact of the proposed activities has been validated using a standardized approach provided by the Austrian Ministry of Education which operates a devoted Department for assessing the impact of innovations in the classroom. The VALNET evaluation framework which is used offers the tools to identify different multicultural dimensions of the educational approaches. Figure 6 shows the results of questionnaires on how the teachers estimated the quality and effectiveness of the DtC portal's content. The left figure shows that 94% of the responders found the quality regarding the pedagogy as high. The right panel shows that 92% of the respondents considered the effectiveness in the learning process to be high as well.

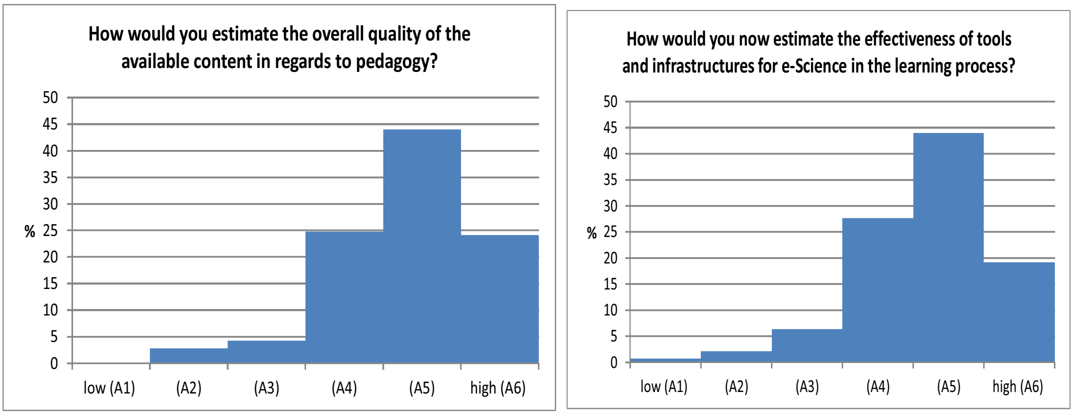

Figure 6. The results of a questionnaire on the validation of the project performed by the BMUKK.

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The goal of the project was to develop an active community of 5,000 teachers and 10,000 students using its portal. The consortium has managed to mobilize an even larger number of users (5,700 teachers and approximately 31,000 students) and to involve them in numerous activities. Furthermore, the evaluation of the impact of these activities to the participants (teachers and students) has been used as a basis of forming a series of guidelines and recommendations for future reference and use from the outreach groups of the research infrastructures and educational policy makers. These guidelines have published in six different languages and are available on the DtC portal.

Beyond the project's life cycle -which is now ended- the members of the consortium will keep up with promoting the tools of Discover the COSMOS and the demonstrators so as to expand the network of teachers and students that are eager to participate in engaging classroom activities by utilizing the *eScience* applications and the tools of this project. Moreover, the technical infrastructure of the DtC portal has been linked with the Open Discovery Space *eLearning* platform (33) that aims to be the central European educational content aggregator in the next three years.

4 The "Global Online Science Labs for Inquiry Learning at school" (Go-Lab) project

The Go-Lab Project (3) started about a year ago, for four years' duration. It aims to open up remote science laboratories, their data archives, and virtual models ("online labs") for large-scale use in education. Go-Lab enables IBSE that promotes acquisition of deep conceptual domain knowledge and inquiry skills and directs students to careers in science.

For students (10 to 18-years old), Go-lab offers the opportunity to perform personalized scientific experiments with online labs in pedagogically structured and scaffolded learning spaces that are extended with social communication facilities. For teachers, Go-Lab offers pedagogical "plug, share, and play" resources through a Web-based interface and a community framework in order to disseminate best practices and find mutual support. A modular approach and inquiry classroom scenarios promotes a seamless incorporation of online labs into the classroom. For lab-owners, Go-Lab provides open interfacing solutions to easily plug in their online labs, construct their virtual didactic counterparts, and share them in the Go-Lab federation of online labs. Go-Lab will thus promote their scientific activities.

The project started with a set of online labs from worldwide renowned research organizations (e.g., CERN, ESA) and from several selected universities and, based on initial in-depth pilots, will gradually improve and expand its series of online labs and associated inquiry learning opportunities with the increasing contribution of teacher and lab-owner communities. In the HEP front, HYPATIA/applet (27), CERNland (34) and LHCgame (35) were among the pilot labs of the first phase and have been demonstrated to thousands of visitors during the CERN Open Days. More advanced and later versions of labs will be evaluated and validated in large scale pilots.

Thus, in summary, the Go-Lab project throughout Europe will expand the resources for teaching science in schools and provide more challenging, authentic and higher-order learning experiences for students. Its sustainability will come from the opportunity for the larger science education community to add new online labs. An open and Web-based community will capitalize on the 'collective intelligence' of students, teachers, and scientists.

5 Large Scale Experimentation Scenarios to Mainstream *eLearning* in Science, Mathematics and Technology in Primary and Secondary Schools

The Inspiring Science Education project (ISE) which started in April 2013 aims at contributing to the implementation of the EC's guidelines for "Mainstream *eLearning* in national policies for the modernization of education and training, including in curricula, assessment of learning outcomes and the professional development of teachers and trainers". It will do so in line with the recommendations of the Rocard Report (5) previously referenced which sets the basics for the introduction of the IBSE approach in the science curricula of the Member States.

The ISE project will design, plan and implement large-scale pilots to stimulate and evaluate innovative use of existing *eLearning* tools and resources (e.g. interactive simulations, educational games, Virtual and Advanced Reality applications, modeling and data analysis tools, *eScience* applications, as well as, digital resources from research centers, science centers and museums and a significant number of *eScience* applications that provide access to a large set of remote laboratories, such as CERN infrastructures, the "Las Cumbres Observatory Global Telescope" network in Hawaii, Australia, Chile, South Africa and the continental US and the ESA Gaia mission) for scientific disciplines and technology, enhancing science.

The project's pilots will involve teachers, students and researchers in collaborative learning activities and will lead to the development of virtual learning communities which will support and encourage cooperation between them. They will act as comprehensive open learning networks where teachers can access their colleagues' course materials, existing *eLearning* tools and resources to be integrated in their own educational scenarios delivered to their students, and shared with other teachers.

The goal is to reach in 40 months, *eLearning* in 5,000 primary and secondary schools in 15 European Counties. The Inspiring Science Education System will be integrated and expand the Open Discovery Space Portal (33), which is considered to be the main vehicle for facilitating the mainstreaming of *eLearning* and the modernization of education in the Member States. Furthermore Inspiring Science Education System will provide the technical means for supporting the orchestration of numerous existing *eLearning* tools and resources in the context of appropriately designed educational scenarios.

ISE is really the first Large Scale pilot project in schools, that the EC is supporting and is one of the main vehicles to mainstream *eLearning* in the member states.

6 Conclusions

The first two projects have been or will shortly be completed. They both created a large on-line community of students and teachers who are effectively using its portals and act as "ambassadors" for the future relevant projects. The community will be further enhanced by the participation of countries which do not belong to the consortium and connecting them either through virtual communities (EUN, Austrian Virtual School) or by digital communication methods (e-Twinning, Facebook, forum on the portal, etc). Both portals will remain active for downloading/uploading scenaria five years after the termination of each project.

The two others projects involve the continuation and enlargement of the completed projects. Are longer in duration, aim to a much wider set of science subjects and will be hopefully Europe's science education backbone and platform.

At the date this paper was written, URLs or links referenced herein were deemed to be useful supplementary material to this paper. The author does not warrant or assumes liability for the content or availability of URLs referenced in this paper.

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