The virtuous integration of Geoscience research and educational projects: examples from the Piemonte region

Lozar Francesca* ([a]), Giardino Marco ([a,b,c]), Magagna Alessandra ([a,b,c]), Palomba Mauro ([a,b]), Perotti Luigi ([a,b]), Selvaggio Ilaria ([c])

[a]) Dipartimento di Scienze della Terra, Università degli Studi di Torino, Via Valperga Caluso, 35, 10125, Torino, Italy. E-mail: francesca.lozar@unito.it

([b]) GeoDidaLab, Via Lago San Michele, 13, 10015, Ivrea (TO), Italy.

([c]) Sesia Val Grande Unesco Global Geopark, Varallo Sesia (VC), Italy

* Corresponding author: Francesca Lozar, Dipartimento di Scienze della Terra, Via Valperga Caluso, 35, 10125, ph. +39 011 6705199 (francesca.lozar@unito.it)

Published on Rendiconti online della Società Geologica Italiana DOI: **https://doi.org/10.3301/ROL.2019.54.**

ABSTRACT

During the MIUR Plan for enhancing scientific degrees (PLS 2015-17), the Italian geological community has been involved in a great effort to bring science and research to the young generations and to help them achieving in-depth knowledge and long lasting success in the STEM sciences.

We offered two field laboratories to Upper secondary education students and teachers, developed from the geotours of the PROGEO-Piemonte, promoting the conservation and dissemination of geological heritage through research and outreach activities. They explore the geology of southern and northern Piemonte integrating research, dissemination and geoscience education, and were designed and led by researchers and wildlife guides in the Langhe-Roero-Monferrato World Heritage Site, and the Sesia Val Grande Global Geopark. To attract the interest of students and teachers we combined an inquiry-based approach, educational activities of cooperative learning, and the use of multimedia tools.

To monitor whether the goals of the PLS were fulfilled, satisfaction questionnaires were administered to both pupils and their teachers. The outcome showed that involving the pupils in field research activities allowed to improve their disciplinary knowledge, their soft skills, and contributed to increase their awareness that the Geosciences are not only interesting, but that they permeate our daily life.

RIASSUNTO

Nell'ambito del Piano Lauree Scientifiche (PLS 2015-17) del MIUR, la comunità geologica italiana è stata coinvolta in un grande sforzo per far meglio conoscere scienza e ricerca alle giovani generazioni e per aiutarle a raggiungere una conoscenza approfondita e un successo duraturo nelle scienze di base.

Grazie al progetto PLS abbiamo offerto due laboratori sul campo a studenti e insegnanti delle scuole superiori, sviluppati sugli itinerari geoturistici di PROGEO-Piemonte, che promuove la conservazione e la diffusione del patrimonio geologico attraverso attività di ricerca e di divulgazione. Essi esplorano la geologia del Piemonte meridionale e settentrionale integrando la ricerca, la divulgazione l'educazione nelle geoscienze, sono stati progettati e guidati da ricercatori universitari e guide naturalistiche nel Langhe-Roero-Monferrato World Heritage Site e nel Sesia Val Grande Global Geopark. Per attirare l'interesse di studenti e insegnanti, abbiamo combinato un approccio conoscitivo basato sull'indagine di terreno e di laboratorio, attività educative di apprendimento cooperativo e l'uso di strumenti multimediali.

Per monitorare se gli obiettivi del PLS fossero stati raggiunti, sono stati proposti questionari di soddisfazione sia agli studenti che ai docenti. Il risultato dell'indagine ha mostrato che coinvolgere studenti e insegnanti in attività di ricerca sul campo ha permesso di migliorare le loro conoscenze disciplinari, le loro competenze trasversali e contribuito ad accrescere la consapevolezza che le Geoscienze non solo sono interessanti, ma permeano la nostra vita quotidiana.

KEY WORDS: Scienze della Terra, Educazione Ambientale, metodo IBSE

KEY WORDS: Earth Science, Environmental Education, IBSE method

INTRODUCTION

In the last decades, it has become evident that mankind needs a more in depth literacy about geological knowledge, in order to build a safer, healthier, and wealthier society (Kellert, 2005). The geological community is more and more involved in the process of increasing the public understanding of science (Durant et al., 1989) not only among under- and post-graduate students, but also among the general public. Moreover, the Geosciences are continuously evolving into new specialized areas of research, and new theories and their advanced applications are produced by combining a diversity of scientific concepts and skills that can provide crucial knowledge for increasing geoscience literacy (De Boer, 2000). Geoscience literacy should be integrated with an increasing international effort for conservation, preservation and public promotion of geosites and geoparks (; Mc Keever & Zouros, 2005) in order to better serve nature conservation, land-use planning, geotourism, and education (Henriques et al., 2011). This goal can be achieved by planning geoscience education and public engagement events based on practical application of field/laboratory activities in protected areas. Such dynamic approach can favor the virtuous integration of Geoscience research and educational projects, and create a better-informed general public on Geoscience contents. In a more general sense, this is a condition for achieving a more positive general attitude towards science and scientists and better relationships between public understanding and public attitude (Durant et al., 1989)

In Italy, the interest in Earth Sciences is scarce among the general public, probably because of the little space that Earth Sciences have in the national education curricula, the poor training of science teachers in geology, resulting in a low literacy of people; and also because media communication quite often reports about geology and geologists only when natural disasters are involved. In order to overcome this low literacy in the geosciences (and in STEM sciences in general; National Science Board, 2006) among Upper secondary education teachers and pupils, and to promote the enrollment of the pupils in STEM degrees, the MIUR (Ministero dell'Istruzione, Università e Ricerca: Italian Ministry for Education, University and Research) has designed a national project ("Piano Lauree Scientifiche": PLS; Italian plan for enhancing scientific degrees), with the aim of improving both pupil literacy and teacher training on a regional base. The program involves Universities offering STEM degrees and pupils and teachers in the Upper secondary education (ISCED level 3).

The existence in Italy of a wide range of geosites (http://sgi.isprambiente.it/geositiweb) and geoparks (www.unesco.it/it/ItaliaNellUnesco/Detail/187), covering the whole range of Geoscience topics, allows to integrate research, education, and conservation, and fulfill the goals of the PLS (Pelfini et al., 2018; Magagna et al., 2013, 2018).

In this paper we show how the field activities, held in two different areas of the Piemonte region (NW Italy; Fig. 1): the Sesia Val Grande UNESCO Global Geopark (C in Fig. 1; www.sesiavalgrandegeopark.it/) and the UNESCO World Heritage "Paesaggi Vitivinicoli di Langhe - Roero e Monferrato" (D-E in Fig. 1; www.paesaggivitivinicoli.it/en/), have the potential to stimulate geoscience interest and understanding and eventually enhance geoscience literacy. We also discuss the results of the satisfaction questionnaires administered to both pupils and teachers with the aim of assessing if integrating geoscience education and basic research on iconic geological heritage sites can achieve the PLS project goal of enhancing geoscience literacy among the Upper secondary education pupils. This qualitative assessment of the outcome of the field trips will inform the team of the Earth Science Department of the University of Torino on how to modify their field laboratories in order to improve the future activities of the PLS project.

Insert Fig. 1

THE CONCEPTUAL AND METHODOLOGICAL FRAMEWORK

At the University of Torino, the Earth Science Department promoted the conservation and dissemination of geological heritage through a three-year long project, PROGEO-Piemonte (PROactive management of GEOlogical heritage in the PIEMONTE region: innovative methods and functional guidelines for promoting geodiversity knowledge and supporting geoconservation activities; Ferrero et al., 2012). The project developed new basic research on nine geographical areas showing peculiar geological aspects, from Alpine metamorphism to glacial landscape. , Geological tours were proposed for enhancing interest in the geoheritage of each area.

During the first three years of the PLS project (2015-17), several laboratory and field activities were offered to Upper secondary education pupils and teachers. Two of the proposed activities deal with the geological evolution of the southern and the northern Piemonte region and are based in

World Heritage Site or global Geopark.

Research scientists and wildlife guides modified the geological tours offered by PROGEO-Piemonte along the Tanaro valley (Langhe-Roero-Monferrato World Heritage) and in the Sesia Val Grande (Global UNESCO Geopark) and offered them, as field laboratories centered on the IBSE (Inquiry Based Science Education) approach, to the teachers and pupils involved in the PLS. The most recent achievements of the research on the topics of the Messinian Salinity Crisis and of the Sesia supervolcano were used to involve pupils and teachers in the most up-to-date research and to improve their interest on geodiversity and understanding of geosciences. The field laboratories combine an inquiry-based approach, cooperative learning, educational activities, and the use of multimedia tools (Magagna et al., 2016), and are organized and sponsored in the frame of the PLS. In order to assess the gains in pupils' and teachers' understanding, engagement, and satisfaction with the informal educational geoscience activities in the field, simple questionnaires with 5 Likert-type items (Smith-Sebasto & D'Costa 1995) were administered to pupils and teachers after the field laboratory.

THE ENHANCEMENT OF SCIENTIFIC DEGREES

The need for enhancing student scientific literacy, and increasing enrollment trends in many STEM programs (and particularly in the Geosciences) require specific educational strategies. This need has been addressed at the national scale in the frame of the last Piano Lauree Scientifiche (PLS, 2015-2017).

The project included activities designed to strengthen Upper secondary education pupils scientific knowledge, guide their choices towards STEM degrees, and train their teachers. The need for the experiential learning approach is particularly strong in the Geosciences, and field trips provide an effective learning model involving emotional, soft and scientific skills in an informal learning environment, where the learner is an active participant rather than a passive recipient (Behrendt &

Franklin, 2014; Jose et al., 2017). Outdoor activities have proven very effective in promoting geoscience literacy (Orion & Hofstein, 1994; Kastens et al., 2009; Streule & Craig, 2016)

The “PLS Geologia” project has been coordinated at the national scale, but local units were able to personalize their activities, integrate ongoing research efforts and the need of the different schools involved to exploit the peculiar geological setting of every region.

GEOHERITAGE AS AN EDUCATIONAL TOOL

The Piemonte region has an outstanding geological heritage, recently enhanced through the research project PROGEO-Piemonte. The project demonstrated that all geoscience topics (from structural geology to stratigraphy, mineralogy, petrology, geomorphology, paleontology, geophysics and geodynamics, applied geology, hydrogeology) that are included in the curriculum in Geology both at the University and Upper secondary education level, are well represented in the geodiversity cropping out across the Piemonte region, where they are often represented by world renowned examples.

The project was devoted both to the development of new basic research and to the inventory of outstanding geosites, deserving preservation as geoheritage sites, and able to enhance the geological literacy of the people living in the area,. Two areas investigated during the project are protected sites, the UNESCO Sesia Valgrande geopark, and the UNESCO world heritage “Paesaggi Vitivinicoli di Langhe - Roero e Monferrato”. They were selected for the implementation of PLS geological field laboratories for their high conceptual content, and their global (Valsesia) and regional (Langhe) relevance (Penas dos Reis & Henriques, 2009). The engagement of pupils in science experiences in their local area, gives the opportunity to bring geoscience to the public in ways that will inform and inspire (King, 2008). Moreover, these sites are accessible all along the year, making them ideal to be explored by pupils during school season. Finally, involving pupils in geoscience field trips is a good practice for achieving the following purposes: 1) To provide first-hand experience, 2) To stimulate interest and motivation, 3) To add relevance to learning and interrelationships, 4) To strengthen observation and perception skills, and 5) To promote personal (and social) development (Michie, 1998).

MATERIALS AND METHODS

THE OPEN AIR LABORATORIES IN THE UNESCO HERITAGE AREAS OF THE PIEMONTE REGION

Two field laboratories were designed with the enquiry-based approach, starting from the geotours previously proposed in the PROGEO-Piemonte project (Lozar et al. 2015; Selvaggio et al., 2016). The aims of the field trips were to show how geoscientists work and cooperate (Kastens et al., 2009), and how they collect data in the field, directly involving the pupils in the collection and, the elaboration of geological data, stimulating and discussing their hypotheses on the processes responsible for the geological history of the area. This cooperative activities, where tutors and pupils work together as peers, serve to trigger pupils' interest and raise their motivation while in the field.

The Sesia Val Grande UNESCO Global Geopark

The geodiversity of the Sesia Val Grande UNESCO Global Geopark (UGG) has an international scientific value. Long-term geological processes, and recent geomorphological phenomena, made accessible several outcrops displaying evidences of dramatic events at different crustal levels: 1) the origin of continental rocks through a wide range of processes, from magmatism, anataxis, high-grade metamorphism, and ductile deformation at depths, 2) the explosive eruption of a supervolcano. For these reasons scientists indicated the Sesia-Val Grande area as a reference section for deep crustal processes (Quick et al., 2009 and references therein).

Along the Sesia Supervolcano path, visitors can observe the products of a supervolcano active around 280 million years ago, formed at the surface and at 25 km depth in the crust. The observation of different geological clues unveil the processes that lead to the formation of the supervolcano, to its collapse in a caldera after a major eruption, and finally to its involvement in the Alpine orogeny, that eventually made possible these observations.

The didactic laboratory was designed and monitored as a multi-stage educational activity; it combines an active learning activity (a practical approach within the Inquiry Based Science Education –IBSE- protocol) with the use of multimedia tools, by proposing the pupils the use of both traditional and virtual tools. The fieldtrip is guided by licensed guides of the local geotourist organization (Associazione Geoparco Sesia Val Grande) in cooperation with the University of Torino (Department of Earth Sciences).

The activity aims at developing the scientific observation and at improving the perception that Geosciences provide useful knowledge for reconstructing long-term history of our planet Earth and for understanding useful tips for everyday life.

The laboratory in the Sesia supervolcano area had three main challenges: 1) how to communicate an Earth Science discover; 2) how to make understandable a complex history of a magmatic process just seeing rocks, without a real volcano; 3) how to increase pupil's awareness on geodiversity and geological knowledge.

The first stage of the laboratory is a field trip on the Sesia supervolcano geosites: pupils are involved in acting as geoscientists. They cooperate in groups with specific roles; observing the outcrops, taking pictures and notes, interpreting the geological map and localising the geosites. The pupils worked in group collecting information - on worksheet and on an application for smartphone or tablet - about the type of the rocks, their age and depth of formation, their position in the geographic space; They also were able to record the track of the field trip, take geotag pictures and notes by using an application suitable for smartphone and tablet. No information is given about the geological history of the supervolcano during this stage. Back to school, a laboratory activity is proposed about the specific weight of the same rocks observed in the field; collected digital data are downloaded and visualised on Google Earth. In the end, the pupils are finally required to find the relationships between the specific weights of the rock samples (e.g. peridotite, granite, diorite, basalt, metapelite), their depth of formation, and their current geographical position. Using all the data collected during the field trip and in the lab, the pupils propose hypotheses for explaining the geological history of the supervolcano. A final explanation is provided by the guides, allowing the pupils to verify their hypotheses; in the end the educators summarize all the processes and the geological history of the ancient supervolcano, pointing out that the area is not presently an active volcano, and that geological processes active in the building of the Alpine chain made accessible the magmatic products of the fossil supervolcano.

The UNESCO World Heritage "Paesaggi Vitivinicoli di Langhe - Roero e Monferrato"

The southern part of the Piemonte region hosts the remains of the Piedmont Basin (PB), located on the inner side of SW Alpine arc . The Cenozoic (Upper Eocene to Messinian) sediments crop out in the southeastern hilly areas of the region. The latest Miocene sediments provide a complete record of the palaeoenvironmental and palaeoclimatic changes that affected the Mediterranean basin during the Messinian Salinity Crisis (MSC) (Dela Pierre et al., 2011; Lozar et al., 2018; Natalicchio et al., 2019). During less than one million years (Dela Pierre et al., 2011and references therein) the Mediterranean connection to the world oceans was severely reduced or blocked, causing a dramatic paleoceanographic event testified by the deposition of huge amount of evaporites, and the drastic change in the marine fossil record, dominated by calcareous plankton in the pre-MSC sediments, and by siliceous plankton in the sediments deposited during the MSC; c) the body and molecular fossil of archea and bacteria has a sudden increase at the base of the MSC (Natalicchio et al. 2019). The sedimentary succession, characterized by sharp marl/shale cycles or shale/gypsum cycles in the lower part, also records climatic (precessional) cycles. The outcrop on the right bank of the Tanaro river, close to the Pollenzo village, offers the opportunity to study the rocks and their fossil content and to understand climate evolution through time as recorded in the strata.

The field laboratory has been preceded by a preliminary lecture introducing general stratigraphy rules (Walter law, e.g.) and observation tools useful to explore the geosite, The short lecture also introduced the Messinian sedimentary succession in the contest of the sedimentary evolution of the PB. In the field laboratory, pupils are involved in acting as geoscientists, Under direct supervision and guidance of researchers and PLS tutors (PhD students in most cases), they are shown how to describe rocks on a fresh surface, how to collect samples in agreement with a previously established strategy (low vs high resolution sampling), how to measure the thickness of the strata and derive the sedimentation rate. Finally, the pupils are guided to interpret the depositional environment of each rock, reasoning on its grain size and its fossil content, and are shown how the collected data describe the geological and climate history of the area. Once the entire stratigraphic succession has been explored, the pupils discuss the existing data (made available both as paper sheet and digital files) and reconstruct the possible geohistory of the area during the Messinian.

The field laboratory thus builds on the importance of strategy of data collection in order to understand sedimentation processes, past environmental and oceanographic changes, and geological time, while fostering the discussion on climate evolution (Lozar et al., 2015). A final explanation in agreement with the most recent scientific models is given for verifying the discussed hypotheses. The laboratory ends with a short and informal lecture on the ice-core record of the last eight climate cycles (Petit et al. 1999), stimulating the discussion on the difference between direct observation of climatic parameters (temperature, air humidity and composition…), the length of their available time series (tenth to hundreds of thousands of years) and the climatic proxies available from the geological record. This in turn helps understanding how climate model designed to predict the current climate evolution benefits of past climate data information.

THE QUESTIONNAIRES: STRUCTURE AND AIMS

The questionnaires were designed to assess the success of the fieldtrips and their effectiveness in stimulating emotional engagement and cognitive improvement in geoscience literacy of the pupils.

Teachers' questionnaires were designed to evaluate the quality and the achievement of the field laboratories, in term of pupils' disciplinary and soft skill improvement.

The short informal satisfaction questionnaire, proposing few questions with 5 Likert-type items (Smith-Sebasto & D'Costa 1995), was given to the pupils and their teachers at the end of the laboratory. The questionnaires were accessible on-line through the Google®-modules platform and the forms were filled once back home. The data were collected anonymously to ensure the freedom to respond openly.

The questionnaire assessed the pupils'interest in the geosciences and the field activities, their satisfaction of the field experience, the general interest of the addressed topics, the ability of the field guides, the improvement of their personal interest in the geosciences through the field activities. Moreover, the questionnaire on the Valsesia laboratory (only) contained a question intending to assess the importance of using digital tools in the field to improve pupils' geological skills.

The teachers' questionnaires were primarily aimed at assessing the agreement of the disciplinary content with the subject taught in the classroom, the efficacy of the preliminary information, the logistics, teaching methods and ability of the guides. Secondarily, the teachers were asked to evaluate their pupils' acquisition of several scientific and soft skills after the field experience. In more detail, we aimed at assessing the improvement on the following scientific skills: observe, describe, analyze complex phenomena of the natural system; analyze qualitatively and quantitatively energy transformation processes; be aware of the potential and limitations of technologies in the cultural and social context in which they are applied; soft skills: communicate; acquire and interpret scientific data; find links and connections; learn to learn; design; problem solving; collaborate and participate; act independently and responsibly.

For the evaluation of the results, the "indifferent" answers was ranked with the negative answers. Only two options (somehow agree, fully agree) were regarded as positive.

RESULTS

The field laboratories were held during autumn 2016 and involved about 100 pupils enrolled in the last year of Liceo Scientifico (Upper secondary education level), aged 18, and 9 teachers. The students were asked to evaluate emotional and cognitive items completing the on-line questionnaire (Table 1). Unfortunately, since the compilation of the questionnaire was not supervised and on a voluntary basis only, we collected 22 answers out of 44 pupils taking part in the Sesia field trip and 43 answers out of 56 pupils taking part in the Pollenzo fieldtrip. All teachers completed the questionnaire. The first result of the survey is thus that the compilation of the questionnaire need to be supervised, in order to collect all the information concerning satisfaction and knowledge increase of the pupils.

The answers show that the interest in the Earth Sciences resulted to be in the average for the pupils taking part in both laboratories (46.5% are not interested or indifferent, 53.5% are somehow or very interested in Pollenzo; 40.9% are not interested or indifferent, 59.1% are somehow or very interested in Sesia Valgrande). A slight interest increase is shown by the pupils that experience the field laboratory in Sesia Valgrande (27.3% increased their interest), while the activities performed in Pollenzo had a higher impact and resulted in a higher increase of the pupil's interest (51.2% increased their interest).

In general the pupils were satisfied during the field laboratory (67.5% and 54.6% in Pollenzo and Sesia Valgrande respectively). The pupils of the Sesia Valgrande laboratory became more aware that the topics they explored should be of general knowledge (volcanic risk; 59.0%), but only 34.9% of the pupils in Pollenzo believed that the paleoclimate knowledge should be of general interest. Both groups were satisfied with the clarity of the exposure of their guides (86.4% and 76.7% in Sesia Valgrande and Pollenzo respectively).

Finally, the pupils felt that the activities had raisen considerably their geoscience knowledge (86.0% and 63.6% in Pollenzo and Sesia Valgrande respectively).

As for the teachers, they were asked to evaluate the degree of satisfaction of the laboratories (Table 1). Few among those involved in the Sesia Val Grande laboratory show a slight dissatisfaction (20% negative impact; 80 % positive impact) with regards to the proposed items (disciplinary content, competence of the guides, logistic in the field, didactic methodologies, and preliminary information about the laboratory). On the contrary, the teachers involved in the Pollenzo laboratory, show high satisfaction with respect to all proposed items.

Insert Table 1

Both groups agree that proposing the pupils to identify with the geoscientists and perform inquiry-based activities was very effective in stimulating their interest and for improving their learning processes.

Teachers were also asked to evaluate the acquired disciplinary and soft skills of their pupils (Table 2). Both groups agreed that the performed activities were very effective (100% positive) in improving the qualitative analytical skills (observe, describe, analyze complex phenomena of the natural system) of the pupils. The quantitative analytical skills (analyze qualitative and quantitative energy transformation processes) were better acquired in the Valsesia (80% positive) than in the Pollenzo laboratory (only 50% positive). The teachers that took part in the Valsesia laboratory were fully positive in recognising the improved awareness of their pupils of the potential and limitations of technologies in the cultural and social context in which they are applied (100% positive in Valsesia, 50% in Pollenzo).

It is very interesting that, according to their teachers, the field laboratory made the pupils increase also their soft skills (Table 3). In particular, best scores were reached in acquiring and interpreting scientific data, in collaborating with their peers, and in participating the proposed activities (100% positive). Finding links and connections among different disciplines was best reached in the Valsesia laboratory (100%) than in the Pollenzo one (75%). Communication skills were better improved in the Pollenzo laboratory (75%) than in the Valsesia (60%). Learning skills were preferentially acquired in the Valsesia laboratory (80%; 50% in Pollenzo). Both laboratory were very effective in making pupils act independently and responsibly (75% Pollenzo; 80% Valsesia).

Problem solving skills were most stimulated in the Valsesia laboratory, where the activities were largely inquiry-based (100%; only 50% in Pollenzo).

To design a research was the less developed skill in both laboratories (40% in Valsesia, 25% in Pollenzo).

Insert Table 2

As for the digital technologies used in the field, digital maps and virtual globes were used only in the Valsesia laboratory. All teachers think that their use stimulated the pupils interest in the topics covered (100% positive), and most of them believe that digital devices are effective in increasing the pupils engagement during the field activities and in the classroom (80% positive). The comparison with the pupils evaluation confirm their positive attitude with digital devices (54.5% fully positive), but somehow unexpectedly it highlight that the pupils were happy with the use of geological maps (63.6% positive), and observing rocks in the natural environment (81.8%). They also recognize the value of the explanation given by the guides both during and after the field activities (77.3% and 90.9% respectively). They only regarded as not very useful the final experiment to evaluate rock density and specific weight (50% positive).

DISCUSSION AND CONCLUSION

The questionnaires were designed to test whether field laboratories led by geoscientists had positive outcomes in the emotional and cognitive processes of Upper secondary education pupils. We tested the perception of both pupils and teachers, in order to better assess our results.

Both groups of pupils (Valsesia and Pollenzo) were moderately interested in the Geosciences, as should be expected in agreement with their enrollment in the scientific Upper secondary education, where science is taught 4 to 6 hours a week.

Most (50% or more) of both groups appreciated the activities in the field. The pupils high appreciation of the activities could be ascribed to the high value of the geological content and to the clarity of the guides when addressing the topics covered during the field laboratories (more than 75% positive in both groups). This good result should be regarded as a direct outcome of the involvement of the scientists in the design, implementation and development of the laboratories. Moreover, their presence and guidance in the field during the didactic activities ensured the correctness of the simulation of the scientific method (IBSE method) and the dissemination of up-to-dated geological knowledge. Moreover, the high appreciation of the activities in both groups (more than 50% of pupil's agreement) suggests that, despite "rough" (Valsesia) or "muddy" (Pollenzo) paths and independently from weather conditions (fair or rainy days), the pupils responded positively to inquiry-based teaching methods performed in the field and led by scientists. The increased interest (51.2% in Pollenzo, 27.3% in Valsesia) and knowledge of Geosciences (86% in Pollenzo, 63.6% in Valsesia) of the pupils testify that the goals of the PLS project (increase knowledge and passion for science among the Upper secondary education pupils) are fulfilled with the activities proposed in PLS laboratories. Another question, aimed at testing if the pupils are aware that science is present in everyday life and everyone should have a better knowledge of the Earth sciences because they deal with everyday issues (Kellert 2005), resulted in somehow different outcomes in the two laboratories. In fact in the Valsesia up to 59.0% of the pupils agree, while only 34.9% in Pollenzo. This discrepancy could be related not to the skills of the guides (both groups of pupils and their teachers regarded their guides as very effective), but maybe to the main subject of the laboratories (geodynamics and volcanology versus stratigraphy and climate change). In fact the Valsesia supervolcano laboratory explores an area where a fossil caldera is exposed to the surface and can be directly studied, thus suggesting that its knowledge could be very useful while studying a present-day analog, such as the Campi Flegrei in Southern Italy, where scientists can not directly access the magmatic features buried at a depth. On the contrary, the understanding that past environmental and climate change recorded in the sedimentary succession at Pollenzo helps building models of present day climate change (thus being very important for our everyday life), was less straightforward, with only 34.9% of the pupils agreeing. This could be related to the generally scarce comprehension of the current climate change, due to the different chronological and spatial scales involved (from hundreds to hundreds of thousands years, from local to global). As such, even if climate change could be regarded as the major issue of our time, its perception as a problem distant from our daily life made the general interest towards past geological analogues very scarce.

The effectiveness of the laboratories was also recognized by the teacher answers, that top ranked the acquisition of both scientific and soft skills by their pupils during the field laboratories, independently from their disciplinary content (Weels 2000, Nicol 2003). Pupil's identification with the geoscientist was appreciated as highly stimulating and could be an additional reason of the high performance of the pupils in improving their geological literacy and love for the geosciences. In more detail, the main difference noted by the teachers of the two groups regards their awareness of the potentials and limits of the use of digital tools during the activities. For the Pollenzo fieldtrip, only 50% of the teachers recognize the increase of this skill among their pupils, possibly because digital data and field mapping tools were largely used in the Valsesia laboratory, while in Pollenzo they were marginal. The teachers consider the use of the app very stimulating and engaging for their students, while the pupils recognize that the use of the geological map and direct observation of rock samples were more effective than the use of the app. This suggests that hands-on activities overcome the effectiveness of the use of digital devices, thus demonstrating that geology is best known and learned by doing, and especially when doing in the field (Kastens et al., 2009). Finally, a virtuous outcome of the project is the possibility that the teachers will replicate the laboratory with the pupils of the following years, using the material provided by the PLS project, with or without the scientist's collaboration (Angeletti et al., 2009).

Summarizing, the main outcomes of the preliminary part of the PLS project involving geoscientists, teachers, and pupils, demonstrate that:

- engaging pupils and their teachers in field laboratories on selected UNESCO heritage sites enhances their interest and geoscience knowledge;
- hands-on activities (e.g. use of geological maps, direct observation of rock samples) are better evaluated than the use of the app when simulating geological research activities;
- involving in the educational activities geoscientists working on specific geoheritage sites (UNESCO World Heritage or Global Geopark), ensures scientific rigor and up-to-dated geological training;
- the collaboration between research and teaching professionals ensures effectiveness of the hands-on activities designed and developed for engaging the pupils;
- the field laboratories enhance equally the scientific and soft skills of the pupils involved, thus confirming the effectiveness of the hands-on method in the natural environment both for disciplinary training and for the formation of values of citizenship (Jose et al., 2017).

Acknowledgments

We are grateful to: the national PLS coordinator, prof. Riccardo Fanti, for sustaining the leading team in carrying out the activities; the "PROGEO-Piemonte" and "GeoDive" projects ("Progetti d'Ateneo" program, cofunded by University of Torino and Compagnia di San Paolo Foundation) for offering educational materials and supporting the mobility of researchers; the Associazione geoturistica Onlus "Sesia Val Grande Geopark" for the cooperation within the PLS; last but not least, the students and teachers who participated with interest to the field and laboratory activities.

References

Angelotti M., Perazzone A., Tonon M.D. & Bertolino F. (2009) - Educating the educators – primary teacher education. In: Gray D., Colucci-Gray L. & Camino E. (eds.), Science, Society and Sustainability. Education and Empowerment for an Uncertain World, Routledge, New York, 154-187.

Behrendt M. & Franklin T. (2014) - A review of research on school field trips and their value in education. International Journal of Environmental & Science Education, 9, 235–245.

Dela Pierre F., Bernardi E., Cavagna S., Clari P., Gennari R., Irace A., Lozar F., Lugli S., Manzi V., Natalicchio M., Roveri M. & Violanti D. (2011). The record of the Messinian salinity crisis in the Tertiary Piedmont Basin (NW Italy): the Alba section revisited. Palaeogeogr. Palaeoclimatol. Palaeoecol., 310, 238–255.

DeBoer, G. E. (2000) - Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. Journal of research in science teaching, 37(6), 582-601.

Durant J.R., Evans G.A. & Thomas G.P. (1989) - The public understanding of science. Nature 340(6), 12-14.

Ferrero E., Giardino M., Lozar F., Giordano E., Belluso E. & Perotti L. (2012) - Geodiversity action plans for the enhancement of geoheritage in the Piemonte region (North-Western Italy). Annals of Geophysics, 55, 487-495.

Henriques M.H., Pena dos Reis R., Brilha J. & Mota T.S. (2011) - Geoconservation as an emerging geoscience. Geoheritage, 3(2),117-128.

Kastens K.A., Manduca C.A., Cervato C., Frodeman R., Goodwin C., Liben L.S., Mogk D.W., Spangler T.C., Stillings N.A. & Titus, S. (2009) - How geoscientists think and learn. Eos, 90(31), 265–272,

Kellert S.R. (2005) – Building for Life: Understanding and Designing the Human-Nature Connection. Island Press, Washington DC, 242 pp.

King C. (2008) - Geoscience education: an overview, Studies in Science Education, 44(2), 187-222.

Jose S., Patrick P.G. & Moseley C. (2017) - Experiential learning theory: the importance of outdoor classrooms in environmental education. International Journal of Science Education, Part B, 7(3), 269-284.

Lozar F., Clari P, Dela Pierre F., Natalicchio M., Bernardi E., Violanti D., Costa E. & Giardino M. (2015) - Virtual Tour of Past Environmental and Climate Change: the Messinian Succession of the Tertiary Piedmont Basin (Italy). Geoheritage, 7 (1), 47-56.

Lozar, F, Violanti D., Bernardi E., Dela Pierre F. & Natalicchio M. (2018) - Identifying the onset of the Messinian salinity crisis: a reassessment of the biochronostratigraphic tools (Piedmont Basin, NW Italy). Newsl. Stratigr. 51 (1), 11–31.

Magagna A., Ferrero E., Giardino M., Lozar F. & Perotti L. (2013) - A Selection of Geological Tours for Promoting the Italian Geological Heritage in the Secondary Schools, Geoheritage, 5 (4), 265-273.

Magagna A., Sperone P., Ferrero E. & Giardino M. (2016) - Riflessioni su un'esperienza didattica di studio del paesaggio geomorfologico con il supporto dello smartphone. Rend. Online Soc. Geol. It., 40, 37-42.

Magagna A., Palomba M., Bovio A., Ferrero E., Gianotti F., Giardino M., Judica L., Perotti L. & Tonon M. D. (2018) - GeoDidaLab: a laboratory for environmental education and research within the Ivrea Morainic Amphitheatre (Turin, NW Italy). Rend. online Soc. Geol. It., 45, 68-76.

Mc Keever P.J. & Zouros N. (2005) - Geoparks: Celebrating Earth heritage, sustaining local communities. Episodes, 28 (4), 274–278.

Michie M. (1998) - Factors influencing secondary science teachers to organise and conduct field trips. Australian Science Teacher's Journal, 44, 43–50.

Natalicchio M., Dela Pierre F., Birgel D., Brumsack H., Carnevale G., Gennari R., Gier S., Lozar, F, Pellegrino L., Sabino M., Schnetger B. & Peckmann J. (2019) - Paleoenvironmental change in a precession-paced succession across the onset of the Messinian salinity crisis: Insight from element geochemistry and molecular fossils. Palaeogeogr. Palaeoclimatol. Palaeoecol., 518, 45–61.

National Science Board (2006) - Science and Engineering Indicators 2006 National Science Foundation, volume 1, NSB 06-01.

Nicol R. (2003) Outdoor education: research topic or universal value? Part three. Journal of Adventure Education and Outdoor Learning, 3, 1, 11-27.

Orion N. & Hofstein A. (1994) - Factors that influence learning during a scientific field trip in a natural environment. Journal of Research in Science Teaching, 31, 1097-1119.

Pelfini M., Fredi P., Bollati I., Coratza P., Fubelli G., Giardino M., Liucci L., Magagna A., Melelli L., Padovani V., Pellegrini L., Perotti L., Piacente S., Vescogni A., Zerboni A. & Pambianchi G. (2018) Developing new approaches and strategies for teaching Physical Geography and Geomorphology: the role of the Italian Association of Physical Geography and Geomorphology (AIGeo). Rend. online Soc. Geol. It., 45, 119-127.

Pena dos Reis R. & Henriques M.H. (2009) - Approaching an integrated qualification and evaluation system of the geological heritage. Geoheritage 1(1), 1-10.

Petit J.R., Jouzel J., Raynaud D., Barkov N.I., Barnola J.-M.,Basile I., Bender M., Chappellaz J., Davisk M., Delaygue G., Delmotte M., Kotlyakov V.M., Legrand M., Lipenkov V.Y., Lorius C., Pépin L., Ritz C., Saltzmank E. & Stievenard M. (1999) - Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Nature, 399, 429-436.

Quick J. E., Sinigoi S., Peressini G., Demarchi G., Wooden J. L. & Sbisà A. (2009) - Magmatic plumbing of a large Permian caldera exposed to a depth of 25 km. Geology, 37, 603-606.

Selvaggio I., Magagna A., Giardino M. (2016) Understanding the Supervolcano with an Inquiry-Based Approach. 7TH International Conference on Global Geoparks UNESCO, 155-155.

Smith-Sebasto N.J. & Ayres D'Costa (1995) - Designing a Likert-Type Scale to Predict Environmentally Responsible Behavior in Undergraduate Students: A Multistep Process. Journal of Environmental Education, 27 (1), 14-20.

Streule M. J. & Craig L. E. (2016) - Social Learning Theories-An Important Design Consideration for Geoscience Fieldwork. Journal of Geoscience Education, 64(2), 101-107.

Weels N.B. (2000) – At home with nature: effects of “Greenness” on Children’s Cognitive Functioning. Environment and Behavior, 32 (6), 775-795.

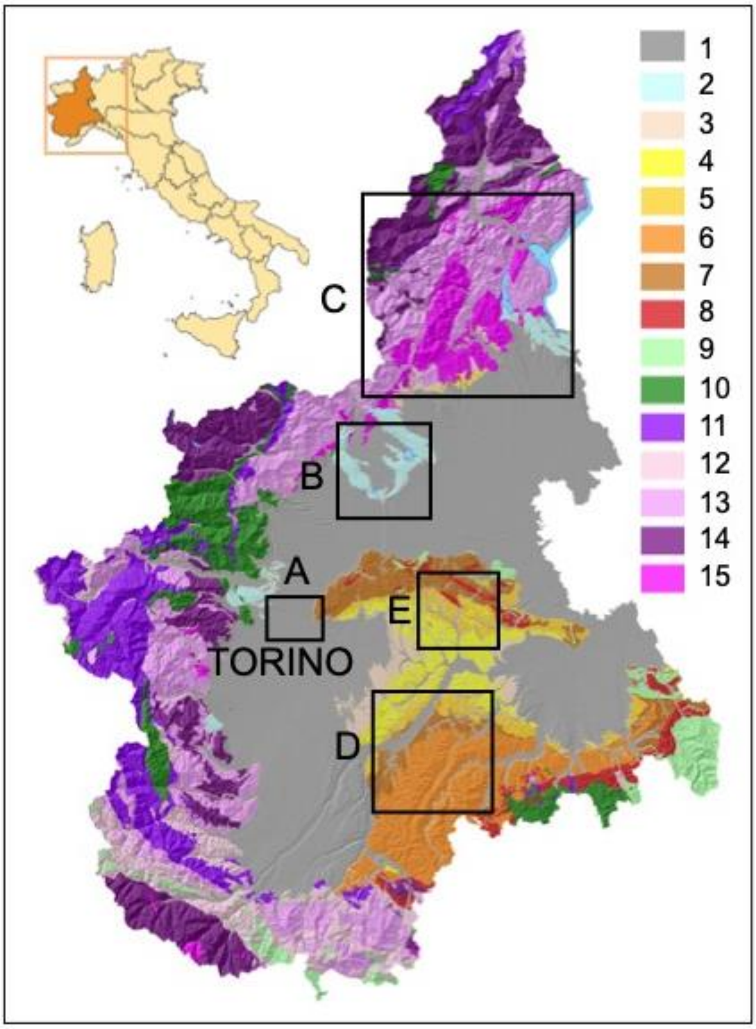

Fig. 1 – The geographic and geological context of the geoscience educational activities in the Piemonte Region, Italy. A) Torino, home of the Earth Science Department (DST, Univ. of Torino).

B) Ivrea, Unesco World Heritage site and home of the GeoDidaLab (DST, Univ. of Torino), in the Ivrea Morainic Amphitheatre. C) The Sesia-Val Grande Unesco Global Geopark. D) Langhe and E) Monferrato areas, territories of the homonymous Unesco World Heritage site.

Legend of the geo-lithological base of the map:

1. Silts, sands, gravels along fluvial valleys and floodplains (Quaternary)
2. Diamictons, sands, silts of main morainic amphitheatres (Quaternary)
3. Clays, interlayered sands and gravels ("Villafranchian", Plio-Quaternary)
4. Fine sands, and local coarse sandstones and calcarenites ("Asti Sands", Pliocene)
5. Clays and clayely marls, locally with gypsum and conglomerate (Middle to Upper Miocene)
6. Marls with rythmic interlayered sands and clays (Miocene)
7. Marly silts with local interlayered sandstone and conglomerate (Upper oligocene – Miocene)
8. Sandstones and conglomerates with minor marls and malrly sandstones (Oligocene)
9. Alternated clays, marls, chaotic clay complexes with limestones ("Flysch", Cretaceous-Eocene)
10. Serpentinite, lherzolite, amphibolite, prasinite, metagabbro units (Jurassic-Cretaceous)
11. Calcschists with intercalated phillades, marbles and prasinites (Jurassic-Cretaceous)
12. Dolostones, limestones and marly sandstones with calcareous breccias (Mesozoic)
13. Fine gneisses, micaschists, fine to coarse schists, quartz-shists (pre-Alpine christalline basement)
14. Coarse gneisses, migmatite gneisses (pre-Alpine christalline basement)
15. Granite, sienite, diorite, gabbro-diorite, ryolite, ignibrite units (Pre- and Late-alpine magmatism).

POLLENZO	Pupil's degree of satisfaction						
ITEM	Strongly disagree	Somehow disagree	indifferent	Somehow agree	Completely agree	TOTAL NEGATIVE	TOTAL POSITIVE
I'm interested in the Earth Sciences		4.6	41.9	46.5	7.0	46.5	53.5
Field activities have improved my interest in the Earth Sciences		9.3	39.5	41.9	9.3	48.8	51.2
I'm satisfied with the activities performed in the field		2.3	30.3	58.1	9.3	32.6	67.4
During the field activities we faced subjects that all should know		23.2	41.9	30.2	4.7	65.1	34.9
The topics covered were clearly exposed		16.3	7.0	48.8	27.9	23.3	76.7
Thanks to the activities my earth science knowledge has increased			14.0	65.0	21.0	14	86

VALSESIA	Pupil's degree of satisfaction						
ITEM	Strongly disagree	Somehow disagree	indifferent	Somehow agree	Completely agree	TOTAL NEGATIVE	TOTAL POSITIVE
I'm interested in the Earth Sciences	9.1	13.6	18.2	50.0	9.1	40.9	59.1
Field activities have improved my interest in the Earth Sciences	9.1	13.6	11	22.8	4.5	72.7	27.3
I'm satisfied with the activities performed in the field	4.5	27.3	13.6	45.5	9.1	45.4	54.6
During the field activities we faced subjects that all should know	9.1	9.1	22.8	54.5	4.5	41.0	59.0
The topics covered were clearly exposed		4.5	9.1	50.0	36.4	13.6	86.4
Thanks to the activities my earth science knowledge has increased		22.8	13.6	50.0	13.6	36.4	63.6

POLLENZO	Teacher's degree of satisfaction						
ITEM	Strongly unsatisfied	Somehow unsatisfied	indifferent	Somehow satisfied	Completely satisfied	**TOTAL NEGATIVE**	**TOTAL POSITIVE**
Disciplinary content in agreement with the High School Science curriculum				25	75		**100**
Competence of the field guides					100		**100**
Logistics					100		**100**
Didactical methods in the field				25	75		**100**
Preliminary information					100		**100**

VALSESIA	Teacher's degree of satisfaction						
ITEM	Strongly unsatisfied	Somehow unsatisfied	indifferent	Somehow satisfied	Completely satisfied	**Negative**	**Positive**
Disciplinary content in agreement with the High School Science curriculum		20		20	60		**100**
Competence of the field guides	20				80	**20**	**80**
Logistics		20		40	40	**20**	**80**
Didactical methods in the field	20			20	60	**20**	**80**
Preliminary information	20				80	**20**	**80**

Table 1 – Assessment of pupil's and teacher's satisfaction.

POLLENZO	Assessment of scientific skills acquisition						
ITEM	Not at all	A little	indifferent	Enough	A lot	**TOTAL NEGATIVE**	**TOTAL POSITIVE**
Observe, describe, analyze complex phenomena of the natural system				50	50		**100**
Analyze qualitatively and quantitatively energy transformation processes		25	25	25	25	**50**	**50**
Be aware of the potential and limitations of technologies in the cultural and social context in which they are applied			50	25	25	**50**	**50**

VALSESIA	Assessment of scientific skills acquisition						
ITEM	Not at all	A little	indifferent	Enough	A lot	**TOTAL NEGATIVE**	**TOTAL POSITIVE**
Observe, describe, analyze complex phenomena of the natural system				40	60		**100**
Analyze qualitatively and quantitatively energy transformation processes		20		60	20	**20**	**80**
Be aware of the potential and limitations of technologies in the cultural and social context in which they are applied				80	20		**100**

POLLENZO	Assessment of soft skills acquisition						
ITEM	Not at all	A little	indifferent	Enough	A lot	**TOTAL NEGATIVE**	**TOTAL POISITIVE**
communicate			25	50	25	**25**	**75**
Acquire and interpret scientific data				50	50	**50**	**50**
Find links and connections			25	25	50	**25**	**75**
Learn to learn			50	25	25	**50**	**50**
Design		25	50		25	**75**	**25**
Problem solving			50	25	25	**50**	**50**
Collaborate and participate				75	25		**100**
Act independently and responsibly			25	50	25	**25**	**75**

VALSESIA	Assessment of soft skills acquisition						
ITEM	Not at all	A little	indifferent	Enough	A lot	**TOTAL NEGATIVE**	**TOTAL POSITIVE**
Communicate		20	20	2	20	**40**	**60**
Acquire and interpret scientific data				60	40		**100**
Find links and connections					100		**100**
Learn to learn			20	80		**20**	**80**
Desing		20	40	20	20	**60**	**40**
Problem solving				60	40		**100**
Collaborate and participate				40	60		**100**
Act independently and responsibly			20	40	40	**20**	**80**

Table 2 – Assessment of pupil's scientific and soft skills increase.