



**Teacher-Scientist-Partnership in Tuscany.
National Research Council- Institute of
Biometeorology, Firenze, Italy**

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Teacher-Scientist-Partnership in Tuscany (Italy)

1. Introduction:

Different activities have been designed, in accordance to students' age and school characteristics. We report about the procedures and the activities supported by FCS Fondazione per il Clima e la Sostenibilità about greenhouse effect and carbon dioxide cycle in the scientific school "Liceo Scientifico Niccolò Copernico" in Prato ("The soil breath", "Photosynthesis, I measure it!" and "CO₂ at school") dealing with the carbon dioxide fluxes and activities run in a secondary level school in Rapolano Terme using a naturally CO₂ enriched areas to introduce students to the concept of greenhouse effect and the effects of elevated CO₂ on plants.

2. Precondition for the projects:

The TSP projects give emphasis to the partnership between scientist and teacher in aiming to support students in learning a scientific methodology to carry out research projects.

The projects deal with the carbon cycle and attention is given to ecological purposes such as the global warming, sustainable lifestyles, ecological citizenship.

The projects are designed for high schools and secondary level schools and they involve a whole classroom. Each project involves one class with one referent teacher who is interested in it by personal motivation or for the interest in a further analysis of a subject with practical experience.

The involved teachers are generally science teachers and collaboration of other matters teachers like foreign language, mathematics or informatics might be integrated in the project to present to the students a wider approach to the topics, in different phases of the project.

The enthusiasm and spirit of collaboration give motivation to the teachers and the scientist as well, for continuing and enforcing the partnership.

In general the project is related to the ministerial program to give the students the possibility to focus a topic and approach to it with new professional instruments.

The teacher usually manages the organization of the project grouping the students to make the practical activities easier and to motivate the community work and collaboration among students. In this way students are able to identify single's potentialities and skills for a future scientific career.

3. The involved schools:

The following schools have playing an active role within the project:

Liceo Scientifico "N. Copernico", Prato, Tuscany

<http://www.copernico.prato.it/>

Liceo Scientifico "N. Copernico" is a higher secondary school (14-19 years old) located in Prato, an industrial town 20 km far from the well known Florence. The school curriculum is based on science learning but also humanistic subjects have relevance. The school is well appreciated for its equipments consisting in a well equipped informatics room and good chemistry and biology laboratories. The school has about 800 students and it has five 'addresses' of study. One of them focuses on science integrating the science ministerial program with *extra-curriculum* activities. The Liceo Scientifico N. Copernico has an important aim in scientific knowledge and the Experimental Course of the School briefly resumes its focal questions in these points (from: http://www.copernico.prato.it/wp/?page_id=25):

- stimulate curiosity, observing capacity, questioning
- develop the capacity of finding rational answers and of comparing
- develop the capacity of objectively judging and critically examining the natural resources
- develop the intellectual capacity with a scientific methodology

The projects have involved three teachers of three classes (about 50 students 16-18 years old) working on different topics.

The lower secondary School Sandro Pertini in Rapolano Terme, Siena, Tuscany

<http://www.icpertini.it/>

The lower secondary School Sandro Pertini is located in Rapolano Terme a small village in the famous rural area of 'Crete Senesi'. The landscape here is characterized by typical rolling hills and the formation of eroded land patches called *calanchi* and *biancane*. The population is concentrated in the main villages and the Institute Sandro Pertini has its main building in Asciano, close to Rapolano Terme. The Middle School in Rapolano Terme has 124 students and is the highest grade of education in town.

Istituto Comprensivo di Borgovalsugana

The Institute is located in the main village of the Valsugana Valley, in the South-Eastern part of the Alps. In recent years the area has suffered the depopulation specially from the small villages spread on the mountains. Borgovalsugana is the main town at the valley bottom where most of the people is employed in the local factories and farms (apple trees and wood fruits are the main agriculture activities). The school gather pupils from the small villages spread in the surrounding villages and have classes from the primary to secondary level.

4. General Attainment targets

The students:

In these kinds of projects the students have the possibility

- to approach the meaning of carbon cycle and of sinks or sources of carbon, climate and climate change by the use of professional instruments
- to achieve a personal ability of experimenting and testing hypothesis
- to learn from practical experiments that human activities (traffic, heating system, personal behavior ...) affect the atmospheric CO₂, thus improving their consciousness about the life quality
- to identify the richness of their territory and their town to learn that constancy and accuracy in observing and describing nature is needed for carrying out a research project
- to discover their own skills in scientific matters and during the different phases of the project (data acquisition, elaboration and discussion of results)
- to access to science and be encouraged to a future scientific career
- to rise motivation in cultural and scientific exchanges by the participation to international events such as the TSP final conference

The scientist:

The projects are an interesting way for the scientist:

- to develop and improve the ability in science popularization specially with young people
- to find motivation in his own personal satisfaction and enjoyment to convey his expertise to non-scientific public
- to increase the sphere of contacts to transfer the results to the local community

The teacher:

Teacher takes advantage from this collaboration because

- they can have access to the use of expensive instruments and can apply real research methodology and protocols and material in their teaching
- they have the opportunity to integrate the theoretical lessons with an experimental phase supported by the scientist and to approach to long term project methodology
- they get new inputs for their research skills that enforce their perspectives of scientific popularization (participating to national conferences, writing articles..)

- they can take advantage of the international perspective of the projects that open the possibility of exchange between students

5. Sequence of activities and management:

The management methodology plays an important role for the development of the activities and to achieve the expected issues; the teacher's pedagogical method is usually based on work groups to encourage the collaboration among the students but also to awake the awareness of the importance and the responsibility of the single's work.

The teacher gives then support to the students during the elaboration of data and the presentation of results, in cooperation with the scientist. The time schedule depends by each projects and it is based on the total amount of hours for the practical activity.

The general sequence of activities is below resumed:

- 1) September-October: as soon as the school year starts, one first meeting with the science teacher is organized for the presentation of the projects and set up of the schedule and the management for the selected one.
- 2) November: the scientist meets the class with one seminar about carbon cycle, CO₂, climate change and to present the project to the students: aim, methodology, tools and tasks while the teacher organizes the groups of students.
- 3) Teacher trainings were organized for the module on meteorology and a seminar with about 100 teachers from primary and lower secondary schools attended to the courses.
- 4) Beginning of the outdoor activity that it is characterized by frequent interaction between scientist and students: the instruments are presented to each work group and the hands-on activity starts applying the scientific protocols for data collection. Most of the projects are long term outdoor activities, therefore due to possible bad weather conditions, the schedule flexibility could be helpful.
- 5) March-April: meetings (3) are organized for data elaboration and discussion of results. Students, but also teachers are commonly new to this kind of elaboration and they could need the scientist's support.
- 6) April: meetings (2) to prepare the presentation of results in poster format and power point presentation for the Final Conference of the project.
- 7) April 27th, 2009: Final Conference of TSP where students presented their results to the foreign colleagues.

6. Description of the projects:

6.1 Meteorology

Since Meteorology is one of the main research subject of the Institute of Biometeorology, several schools in the past years have asked frontal lessons to the Institute's scientists and we decided to bring and to improve the teachers knowledge on the topic integrating the scientific expertise with lessons feasible in different grades of classes. The topic in fact easily can be integrated with the scholar ministerial program as it regards the climate characteristics of the region and thus linked to economy and its exploitation. To make the lessons pleasant and funny, we brought material for preparing and learning how to build simple tools.

Target: in-service teachers of primary and secondary schools (about 100)

Pupils of primary schools (about 60) and Secondary school (4)

Time needed: one year with 8 hours of course for pupils and 4 hours for teacher training

Instruments:

The peculiarity of the project was characterized by the use of simple material for the creation of simple meteorology tools, allowing the understanding of the theory behind the phenomena and the real devices. The teachers were provided with videos and a booklet to reproduce the instruments construction in class

and the scientist, during the visits, run some experiments with pupils to make clear the physics of meteorological parameters. For example, we taught to build a simple version of Galileo's thermometer, the barometer, and the anemometer.

Pupils shown enthusiasm and interest and willing of interaction during the practical phase of the lessons, demonstrating that this kind of activities encourages pupils to inquiry, explore, observe, touch and create things and is well appreciated both by pupils and teachers.



For pupils of the Secondary school in Prato we proposed an activity based on the use of meteorological simple devices (thermometer for Min and Max temperatures and glass pluviometer) involving directly a little group of students. This activity aimed to get awareness about the climate of their territory, in fact, students coming from villages located in different sites of the Bisenzio watershed, at different altitudes and different expositions, were chosen for installing those instruments in their gardens. Every day they were committed to collect the data of temperatures and rain filling the worksheet 'Meteo at home' prepared for the activity. Helped by the teachers, they elaborated the collected data and compared the different locations.

Methodology

A former teacher training has the aim to involve and train teachers on meteorology, understanding the physics of meteorological phenomena and explaining about the history of meteorology. A collection of experiments and movies was given to those directly involved teachers to be able to run experiments in their classroom. The scientists met the pupils 4 times a year with lessons and experiments about meteorology and building together meteorological tools.

The older students involved in the project Meteo at home, attended 2 lessons, one was an introduction to the meteorology and the atmosphere, the second one was a seminar on the climate change. The tools were distributed to the students that had instructions for the proper use and installation, the teachers as well were trained and were committed to verify the students work.

Data elaboration and discussion:

The students working in the project Meteo at home managed to collect data for short periods a month due to various problems (from the scarce involvement of parents, who sometimes emptied the glass pluviometer without taking note of rains, to vacations..). In any case they collected some good data that were elaborated in Excel with a little help by the teacher and the scientist. Finally they could appreciate the difference in temperature between the big town in the valley and one small village on the hill.

Teaching material and modules for teacher training:

Lezioni di meteorologia (teacher training material) (Italian)

Raccolta di esperimenti per la meteorologia e l'anidride carbonica (Italian) Booklet with experiments on meteorology and movies with indications about how to build simple meteorological tools

Worksheet: Il meteo a casa mia/Meteo_at_home (Italian/English)

I cambiamenti climatici (Italian)

Il Cambiamento globale – il cambiamento locale. Dal Lagorai al mondo e viceversa (Italian)

6.2 Photosynthesis, I measure it!

The photosynthesis is the most important biological process occurring within the carbon cycle (due to the the autotrophic organisms -by the photosynthesis- absorption of atmospheric CO₂), and this project gives a pragmatic approach to the theoretical concepts introducing also a new subject like 'plant eco-physiology'.

The preliminary seminar explains the carbon cycle and the role of vegetation and introduce the photosynthesis with emphasis on the environmental factor that can affect the physiological plant behavior and on the fundamental parameters such as Photosynthetically Active Radiation, stomatal conductance, transpiration and CO₂ absorption that will be monitored by the students during the practical part of the project.

The measurement campaign was carried out in the garden of the school that counts some typical Mediterranean evergreen species such as shrubs of Nerium oleander, Prunus laurocerasus, Viburnus tinus. The measurements on evergreen species might start in the winter even if it's cold and the plant activity is reduced. The aim of this activity focused on the role of vegetation within the carbon cycle and the relationship between environmental conditions and photosynthesis during different seasons.

The plant eco-physiology was an innovative subject that teachers have deepened by the use of professional tools.

Target: students of age 17-18, ; Number of students: 15

Time needed: One year.

The project run during the ordinary science lesson. A total amount of 25 hours were spent by the students.

Instruments:

- 1) Infra Red Gas Analyser (CIRAS-1) with the Chamber for Photosynthesis Measurements (cuvette)measures continuously the flux of CO₂ coming from the sealed leaf in the cuvette and reports the amount of CO₂ that has been absorbed (or produced by respiration)by the leaf. The maximum values of assimilation are measured when the solar radiation and the intensity of the Photosynthetically Active Radiation is high (more than 1000 μmol/m² sec). The instrument instantaneously gives many other parameters such as stomatal conductance, transpiration rate, leaf temperature that the students can observe during the measurement. The data collection is done manually to enforce the awareness of the accuracy importance to get good data,
- 2) PC for elaboration with a worksheets program.



Fig. 1 CIRAS-1 Portable Photosynthesis System is made by three the Portable IRG and bythe Leaf Cuvette.

Methodology for outdoor activity:

- 1) Species selected: Prunus laurocerasus with its spherical, rich big and thick leaves; Nerium oleander and Viburnus tinus
- 2) From the sun exposed part of the canopy, green and wealthy 'sun' and 'shade' leaves from the lower and the upper part of the canopy were selected for the measurements. (For the measurement the leaves have to be lightened directly by the solar radiation).
- 3) The measurement starts when the leaf is sealed inside the cuvette. The parameters are instantaneously shown in the display of CIRAS and current values can be read and recorded manually. This means that the values could be significantly influenced by the accuracy in handling the instrument.

- 4) Data download is cured by the scientist that finally sends the Excel file with the original data to the teacher and the students as well that start the data elaboration.
- 5) They produced 1 poster that was presented during the Final Conference in April 2009.



Fig.2 Students using CIRAS-1 in the garden

Data elaboration and discussion:

The amount of data is significant and completely new to the most part of the students. The most important parameters to focus on are:

- dCO_2 = differential concentration of CO_2 (ppm) from an initial concentration;
- CO_2 assimilation rate or respiration rate (in $\mu mol CO_2/m^2 sec$);
- PAR, Photosynthetically Active Radiation (in $\mu mol/m^2 sec$);
- H_2O lost (transpiration in $mol/m^2 sec$);
- stomatal conductance (in $mol/m^2 sec$); temperature of leaf (in $^{\circ}C$).

The data elaboration needs the presence of the scientist that also stimulates discussions and formulation of hypothesis specially when anomalies are observed.

Measurements are not reproducible and strictly dependent by several condition: meteorology, sky cover, water stress...

Results

Students found easier to work on the data collected from one single leaf, observing the behavior of each parameters during the measurement. Sun and shade leaves were observed.

They produced graphs about the relevant parameters such as transpiration (water lost), Photosynthesis and stomatal conductance and took into consideration other parameters like PAR (light intensity influence the stomatal openings) and leaf temperature (as stress indicator when the leaf is long time sealed) to discuss the results. Generally they observed that Photosynthesis is influenced by the leaf temperature: the increasing of the temperature induces a stress condition and the gas exchanges are reduced.

Some graphs are visible at: <http://web.fi.ibimet.cnr.it/carboschools/>

Teaching materials and modules for teacher training:

Ppt presentation in Italian about the subject (Photosynthesis and the carbon cycle)

Il Cambiamento Globale....ma cosa cambia? (Global Change)

References and web sites:

Grassi G, 2006. Fino a che età le foreste accumulano carbonio? *Forest@ 3* (4): 459-460. [online] URL: <http://www.sisef.it/>.

Larcher W., 1993. *Ökologie der Pflanzen*. ©E. Ulmer Verlag. Stuttgart.

Il Ciclo del Carbonio nell'Ambiente, Università di Parma - Scienze e tecnologie chimiche.

CIRAS-1 Portable Photosynthesis System Operator's Manual Version 1.20, © 2000 PP Systems. All Rights Reserved, 2003.

www.carboschools.org

6.3 The soil breaths

Terrestrial areas are mostly covered by soils and several factors such as climate conditions, nature of the rocks, physic and biological processes influence the soil development.

The land cover (waters, vegetation but also soils) correspond to a sink of carbon, for instance soils stock the carbon in form of complex organic molecules but also gas.. produced by decomposition due to macro-micro organisms and by mineralization processes by bacteria. The CO₂ is also produced by macro-organisms and root respiration and in this way it comes back to atmosphere called as 'soil respiration'.

The aim of the project is to understand the role of soils and land cover within the carbon cycle, due to the strong influence that human activities but also land management and agricultural practice have on the atmospheric gas composition. For example traditional agricultural practices, based on tillage, and practices of pruning remainders burning contribute to the rapid mineralization of the organic matter with the rapid release of CO₂ to atmosphere; the fuel used for machinery as well is an external source of Carbon dioxide. Atmospheric CO₂ is so influenced by the land characteristics: land cover, land management and human activities.

The measurement campaign has been done in the school garden that is covered all over the year by mixed grasses but also different kinds of cover were investigated.

Target: students of age 16-17; Number of students: 15

Time needed: One year.

The project runs in 40 hours. Three different soil conditions have been observed spending about 20-30 minutes for each of them. Soil respiration has been surveyed during two seasons in three areas.

Instruments:

- 1) Infra Red Gas Analyzer with a Chamber for Soil respiration Measurements (EGM-1, PPsystem, Hitchin, UK). Data acquisition regards the CO₂ concentration (ppm) and the CO₂ efflux from the soil (gCO₂/m² hr).
- 2) Temperature Probe Sensor measures the soil temperature (°C).
- 3) Time domain reflectometer is used for soil humidity for the first centimeters of thick (%).
- 4) PC for elaboration with a worksheets program.

Methodology for outdoor activity:

- 1) Selection of the three areas in the garden. One was used for measurements in soil with dense grass cover; the second one, 12 m² wide, was prepared as vegetable garden for measurements on bare soil and the third one was under pine trees (*Pinus pinea* L.) cover. The school, not equipped by agricultural machines and any irrigation system, provided simple tools like hoes and rakes.
- 2) The outdoor activity was carried out over 5 months with fortnightly meetings of two-three hours each. The class was divided in groups of 4-5 students and each group worked about 20 – 30 minutes during every meeting while the rest of the students rested in classroom for the ordinary science's lesson.
- 3) Students reported the data in Excel and worked on elaboration: those with informatics skills were the most motivate.
- 4) They produced 1 poster and 1 oral presentation in power point that were presented during the Final Conference in April 2009.

Additional activities such as respiration produced by the biological organisms (worms), quantification of roots from soil samples were done pushed up by the students curiosity.



Fig.3 Students works on soil respiration measurements

Data elaboration and discussion:

The amount of data was significant and completely new for the students. During the elaboration and discussion phase of the project they realized that environmental parameters are not easy to discuss because influenced by several other factors. They animated an interesting brainstorming to get conclusions and explanations of their results. They grown the awareness of the importance of accuracy and constancy of each of them with responsibility for the group's work.

For carrying out the elaboration the students should have a basic knowledge of statistics and Excel for the representation of results in graphs.

The scientist supports students and teacher during the data elaboration and during the preparation of the presentation of results for dissemination. The first presentation of the project occurred during the Science Week in March 2009 to a general public. Students prepared a demonstration of their project and posters. They also prepared one poster translated in English to be presented at the Final Conference of TSP project and one oral presentation for Swedish guests in visit at the school.

This has been an important event to rise the students skills on communication in a foreign language and a good opportunity for showing their results.

Results

Soil respiration measurements obtained the highest values at the moment of the preparation of the vegetable garden. In fact, the change in soil porosity and turning upside the ground facilitates mineralization processes and gas diffusion and emission to atmosphere is easier.

This result has moved discussions about the role of agricultural techniques in relation to the carbon stock and CO₂ emissions in atmosphere. Then that soil has not being worked anymore, neither watered and lowest values of soil respiration have been observed perhaps due to the drought and scarcity of roots and biomass. Students then surveyed other soil parameters such as soil temperature and they observed for instance that the pine cover with its thick litter protects in winter the soil from freezing.

Teaching materials and modules for teacher training:

Ppt presentation for the first seminar about soil respiration (in Italian: *Il suolo e il ciclo del carbonio*)

References and web sites:

Mediterraneo e Italia nel cambiamento globale: un ponte tra scienza e società (Proceedings of the First Italian IGBP Conference, Paestum 14-16 November 2002) selection of articles:

M. F. Cotrufo, 2002. Carbon sequestration in soils under global environmental change.

G. Martignon, F. Sala, P. Boldori, F. Apadula, L. Sormani, 2002. The GREEN-CARB Territorial Information System for a net carbon sequestration assessment of agro-ecosystems.

Larcher W., 1993. Ökologie der Pflanzen. ©E. Ulmer Verlag. Stuttgart.

Il Biosegreto di Eldorado (newspaper article about the sustainable and innovative –for developed countries- agricultural practice of Biochar)

www.carboschools.org

6.4 Measuring CO₂ at school

Since the beginning of the industrial revolution the atmospheric CO₂ and other green house gases concentration has been increasing affecting the natural Greenhouse Effect and, as a chain, Earth's ecosystems. aim of the project is rising the awareness that human activities and lifestyles can impact the air quality of urban environments with scarce benefits in terms of welfare.

The students in fact investigate the concentration of CO₂ inside their school, using a portable EGM-1 gas analyzer and the Vaisala gas analyzer connected to the Meteorological Station for the measurements of the atmosphere.

Target: students of age 16-17; number of students: 25

Time needed: 20 hours.

The CO₂ concentration is measured inside the school, in several and different (for use and size) rooms and outside the school.

Instruments:

- 1) Handle Gas Analyzer (EGM-1, PPSYSTEM, Hitchin, UK) for measuring the concentration of CO₂ in different places of the school: empty and plenty rooms, corridor, outdoor etc..
- 2) Meteorological station (6152EU* Vantage Pro2 wireless Weather Station, Davis, USA) and atmospheric CO₂ gas analyzer (GMP 343 Carbocap Carbon Dioxide Probe, Vaisala) that have been proposed, on a National basis by the Center for Isotope Research, University of Groningen, Holland.

Methodology for outdoor activity:

- 1) The class was divided in groups, each of them explored different environments:
 - Traffic road at the light stop,
 - closed rooms inside the main 3 floors building of the school;
 - closed rooms inside the secondary building of the school (1 floor building);
 - open and inner spaces in different moments: before, during and after the coffee break;
 - vertical transect along the external fire stairs;
 - concentration of atmospheric CO₂ recorded by the Vaisala sensor
- 2) The outdoor activity was carried out twice, in winter and in spring. Each group worked 20-30 minutes during the data acquisition meetings while the rest of the students rested in classroom. During the outdoor activity the students use the instrument and the CO₂ values were recorded manually, then the students elaborated the data in Excel and worked on graphic representation of results.
- 3) They produced 5 posters and two of them were presented at the Final Conference in April 2009.

Additional experiments for testing the chemical and physical properties of CO₂ have been designed by the students and shown during the Science Week in March.



Fig.2 Practical outdoor activity and demonstration of experiments on CO₂ properties during the Science Week

Data elaboration and discussion:

The students need a basic knowledge of statistics and skills in the use of Excel for the data elaboration. The CO₂ in urban atmosphere is strictly related to the human inputs (traffic, heating systems..) and life styles, thanks to these kind of projects they mature the awareness that all of us produce an impact in our local environment.

Students also run simple experiments to understand the chemical aspects and the physical properties of CO₂ (weight, color, solubility, pH alteration capacity..).

Results

The project obtained good results moving also the young's sensitiveness to thematic related to the air pollution, green house effect in relation with our common habits (traffic; heating systems; smoking..) and their impact on atmosphere.

The vertical transect shown highest values on the top of the roof surely due to the influence of the smoke (released by the heating systems).

The Science Week organized by the school was the first event in which students presented the project to the general public running experiments on CO₂ properties.

Posters in foreign language (English) were presented during the Final Conference of the Project, April 2009.

Teaching materials and modules for teacher training:

Ppt presentations for the seminars about CO₂ in atmosphere and the carbon cycle:

L'anidride carbonica in atmosfera e il ciclo del carbonio (in italian)

Stazioni Meteorologiche Didattiche corredate di Analizzatore di CO₂(in italian)

Manual for Excel use and for meteorological data elaboration (in italian)

WORKSHEET_TRANSECT DELLA CO₂ (in italian)

Web sites:

ec.europa.eu/environment/climat/campaign/resources/publication_en.htm

<http://www.explora.rai.it/>

www.carboschools.org

6.5 The doline of Bossoleto as laboratory for greenhouse effect

The area of Rapolano Terme (Siena province), is one of the several thermal sites in the Siena-Radicofani basin, originated by the volcanic activity of the south-eastern part of the region. The Bossoleto doline is a private and closed area (~80 m in diameter, and ~6 m in depth) where gas emissions (mainly composed by CO₂ with traces of hydrogen sulphide and other gases) in combination with topography manifest the Greenhouse Effect. Specially in the early morning of sunny days at the bottom of the crater the air temperature shows a rapid increase, associated with the high presence of CO₂ and stable atmospheric conditions.

High CO₂ concentrations also have characterized the vegetation spatial definition. This environment has been largely used for studying the effects of elevated atmospheric CO₂ concentrations on plants (Raschi et al., 1999), for this reason it is an important laboratory for teaching these subjects.

Multidisciplinary field visits for secondary school students have been organized, generally led by a geologist and a forester and experiments were carried out. They also represent an opportunity for the valorization of the rural territory, starting from the young generations.

Target: students of age 11-14; number of students: 40

Time needed: one year.

Field visits are rare, once or twice a year because of the lack of funds and due to the absence of any kind of public transport connecting the village to Bossoleto.

Methodology for outdoor activity:

- 1) The project starts with a frontal lesson held by the scientist in classroom about various topics: atmospheric CO₂, the greenhouse effect, signs of climate change with particular attention on examples at local scale.
- 2) In the first field visit the students observed the landscape inside and outside the doline. Looking around they discovered the peculiarities of the doline and it stimulated curiosity and lots of questions. Simple experiments tested the presence of CO₂ and its properties and the concentration of CO₂ was shown using the handheld gas analyzer (EGM-1, PPsystem, Hitchin, UK). The hands-on activity about CO₂ influence on plant growing was set up: students filled 10 pots with soil and seeded the same quantity of barley. 5 of them were brought to the school (3 Km far from Bossoleto) and 5 of them remained in the CO₂ enriched air.
- 3) The observation of those plants growing in the school was organized and managed by the teacher with material supported by the scientist (forms for the observation of phenology stadium) while, unfortunately, the plants in Bossoleto were observed only during the rare field visits. So only the differences at the final stadium were actually compared (final height, spike size)

Instruments:

- 1) The portable Gas Analyzer (EGM-1, PPSYSTEM, Hitchin, UK) for atmospheric CO₂ concentration
- 2) Simple tools (candle, balloon, matches, seeds and pots)
- 3) thermometers



Field visit at Bossoleto and pot with barley

Results

Results of the project have been presented in a movie format with students describing the scenes related to the project.

The movie has been presented to the Carboschools+ project partners during in visit at Rapolano on 30th of April 2009.

Teaching materials and modules for teacher training:

Ppt presentation for the first seminar about CO₂ in atmosphere and the global change signals.

Leaflet: 'La mofeta del Bossoleto; naturally Carbon Dioxide enriched area'.

Relationship between tectonics and fluid circulation, 32nd International Geological Congress, Field sight near Rapolano Terme (Siena, Tuscany) Vol n° 3 - from D01 to P13.

<http://leonardodavinci.csa.fi.it/osservatorio/pietre-firenze/orogenesi.htm>

[http://www.regione.emilia-](http://www.regione.emilia-romagna.it/GEOLOGIA/divulgazione/pianeta_terra/16_appennini/appennini.htm)

[romagna.it/GEOLOGIA/divulgazione/pianeta_terra/16_appennini/appennini.htm](http://www.regione.emilia-romagna.it/GEOLOGIA/divulgazione/pianeta_terra/16_appennini/appennini.htm)

http://www.vialattea.net/esperti/php/risposta_printable.php?num=9463

7. Results

Each project had its own experimental results that were presented in form of posters or power point presentation during the Final Conference of the Project and other regional events such as the Science Week.

In general, as the work of the scientists is scarcely known to students; experiments and long term practical activities have an interesting development in terms of social interaction among students and external partners. Bringing science experiments and activities related to actual scientific matters, attention to the citizenship and environmental ethics regarding the human causes of climate change is pushed up. From this point of view, the project was of paramount importance to embed the global change problem in a context of local activities, features of the territory and professional choices: students worked in groups using instruments in their local environment (their school and their town) and this leads them to a greater consciousness about the atmospheric carbon dioxide amount and its environmental consequences.

8. Valuation of results

Students

Students like these kinds of practical scientific activities especially if they respond and focus on actual thematic also regarding the ministerial program. In the Italian school system practical activities are generally little experienced even in those well equipped schools. For this reason students appreciated the innovativeness of the topics and the use of new instruments.

Experimenting real research activities, they reached the awareness that environmental parameters are not reproducible but conditioned by many variables, thus, to keep low the probability of errors, accuracy in the application of the scientific methodology is fundamental.

The weakness of this kind of activities consists in the use of tools and instruments with the single's responsibility that is basic for the group's results. They like very much the international character of the project and the real opportunity to get in contact with foreign colleagues.

Teachers

Teachers are conscious of the importance of this kind of projects specially if they push up the youth's ecological sensitiveness. The presence of professional staff and instruments allow to run activities they have never run before and to get new material. Constraints are due to lack of funds and bureaucracy that often limits the purchasing of new material or constraints field visits.

These projects are furthermore important because they raise the school's notoriety and give the teachers the opportunity to enlarge their sphere of contacts, participating to popularization actions such as workshops or conferences and to enlarge the possibility of students exchanges.

The constraints consist in scarce availability of funding and the scarce interaction and participation of other teachers.

Scientists:

This kind of activities gives good satisfaction when the interaction with teachers and students is a way to implement the projects and motivate the partnership.

The elaboration of data requires many efforts therefore much more time should be given to this activities or in alternative, the collaboration of other teachers could be stimulated. The constraint is closely linked to the age of students and to the school structure that often limits the freedom of action. Science dissemination for several years has been considered the scientist's secondary activity usually pushed by a moral responsibility and sense of the duty. Nowadays the science popularization is becoming moreover important and common from a professional point of view as well: publications, conferences, fairs are common and interested on it and scientists can have their professional feedback.

9. Generalizations / best practice

Within the partnership researchers and teachers have to take into account the recurrent difficulties and loss of time often due to bureaucracy, school time schedule.. and lack of funds that often preclude the evolvement of the activity and influence its feedback. In spite of these problems, the hands-on activities represent an excellent way of doing science at school, and growing up the ecological awareness of the students especially if they concretely deal with environmental thematic.

Then, based on group's work, they let find out the student's skills and work-group aptitude. The work in 'community' and not 'by single' inspires interaction *intra* and *inter* partnership.

A general recommendation for a long-life cooperation is the attention to the class management by applying simple roles such as defining work groups and fixing deadlines for the different phases of the project. Again, the collaboration with other teachers (foreign language, informatics, physics and so on) as well should be stimulated to better and easier understand different aspects of the topic.

Working with young pupils, but also with older pupils it is important to bring at school new ideas and new ways of doing science, including movies, running experiments, creating and building instruments.

10. Teaching materials:

Power point presentations (in Italian) about the taught subjects:

"*Photosynthesis and the carbon cycle*" La fotosintesi e il ciclo del carbonio (Italian)

"*Soils and the carbon cycle*" I suoli e il ciclo del carbonio (Italian)

"*Climate change*" I cambiamenti climatici (Italian)

"*CO2 in atmosphere and the carbon cycle*" La CO2 in atmosfera e il ciclo del carbonio (Italian)

"*Meteorology, lessons*" Lezioni di meteorologia (teacher training material) (Italian)

"Booklet of experiments for meteorology and carbon dioxide" Raccolta di esperimenti per la meteorologia e l'anidride carbonica (Italian)

Filmati sulla meteorologia (movies with indications about how to build simple meteorological tools)

Worksheet: Il meteo a casa mia/Meteo_at_home (Italian/English)

References and web sites:

Grassi G, 2006. Fino a che età le foreste accumulano carbonio? *Forest@ 3* (4): 459-460. [online] URL: <http://www.sisef.it/>.

Mediterraneo e Italia nel cambiamento globale: un ponte tra scienza e società (Proceedings of the First Italian IGBP Conference, Paestum 14-16 November 2002) selection of articles:

M. F. Cotrufo, 2002. Carbon sequestration in soils under global environmental change.

G. Martignon, F. Sala, P. Boldori, F. Apadula, L. Sormani, 2002. The GREEN-CARB Territorial Information System for a net carbon sequestration assessment of agro-ecosystems.

Il Ciclo del Carbonio nell'Ambiente, Università di Parma - Scienze e tecnologie chimiche.

Il Biosegreto di Eldorado (newspaper article about the sustainable and innovative –for developed countries- agricultural practice of Biochar)-article of national newspaper-

CIRAS-1 Portable Photosynthesis System Operator's Manual Version 1.20, © 2000 PP Systems. All Rights Reserved, 2003.

Manual for Excel use and for meteorological data elaboration (in italian)

Relationship between tectonics and fluid circulation, 32nd International Geological Congress, Field sight near Rapolano Terme (Siena, Tuscany) Vol n° 3 - from D01 to P13.

Leaflet: *'La mofeta del Bossoleto; naturally Carbon Dioxide enriched area'*.

www.carboschools.org (collection of material and websites)

ec.europa.eu/environment/climat/campaign/resources/publication_en.htm

<http://www.explora.rai.it/> (collections of web-seminars)

<http://leonardodavinci.csa.fi.it/osservatorio/pietre-firenze/orogenesi.htm>

[http://www.regione.emilia-](http://www.regione.emilia-romagna.it/GEOLOGIA/divulgazione/pianeta_terra/16_appennini/appennini.htm)

[romagna.it/GEOLOGIA/divulgazione/pianeta_terra/16_appennini/appennini.htm](http://www.regione.emilia-romagna.it/GEOLOGIA/divulgazione/pianeta_terra/16_appennini/appennini.htm)

http://www.vialattea.net/esperti/php/risposta_printable.php?num=9463

<http://www.ibimet.cnr.it/web-ring/progetto-meteo-school>