The European Experience of Educational Seismology

A. Zollo, A. Bobbio, J.L. Berenguer, F. Courboulex, P. Denton, G. Festa, A. Sauron, S. Solarino, F. Haslinger, and D. Giardini

1 Introduction

Earthquakes are the manifestation of a dynamic Earth and easily catch the attention and imagination of people. These phenomena are very well known by any citizen because of the great impact that a big earthquake has on society and the interest of the media in the strongest events. One of the best defences against the effects of earthquakes is citizens who are aware of earthquake risks and consequences, who are well educated in the science of earthquakes, who understand what causes earthquakes, how often, how large and where they are likely to occur and how the damaging effects of earthquakes can be mitigated through appropriate actions, both

A. Zollo (✉) • G. Festa
Dipartimento di Scienze Fisiche, Università degli Studi di Napoli "Federico II", Naples, Italy
e-mail: aldo.zollo@unina.it

A. Bobbio
Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Sezione di Napoli, Naples, Italy

J.L. Berenguer
Centre International de Valbonne, Valbonne, France

Université de Nice Sophia Antipolis, CNRS, Géoazur, Observatoire de la Côte d'Azur, Valbonne, France

F. Courboulex
Université de Nice Sophia Antipolis, CNRS, Géoazur, Observatoire de la Côte d'Azur, Valbonne, France

P. Denton
British Geological Survey, Keyworth, UK

A. Sauron • F. Haslinger • D. Giardini
Schweizerisher Erdbebendienst (ETH), Zurich, Switzerland

S. Solarino
Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Genova, Italy

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European projects: typologies and financial supports

Country	Financial support	School Type	# Schools	Researcher Institutes
Italy	Department of Civil Protecion, INGV; European	Secondary and High schools	15	Universities, INGV
France	European and National	Secondary and High schools	60	CNRS, Geoauzur
Switzerland	European and national	Secondary and High schools	28	ETH
UK	UK Financial Support: Geological Survey Charities OilCompanies Universities	Secondary schools	150	British Geological Survey, UK Universities
Portugal	National	Secondary and High schools	5	University of Lisbon
Greece	National	High schools	5	Patras Seismological laboratory
Ireland	National	Secondary schools	50	DIAS, BGS, IRIS

Fig. 1 A scheme of European projects describing the typologies and financial supports

at individual and community levels. Increasing our knowledge about earthquake phenomena and their impact at the Earth's surface is an important step towards the education and the disaster preparedness of a population in high seismic risk regions.

In this sense, educational seismology represents an efficient vehicle of communication, allowing us to teach and learn about earthquakes and seismic wave impacts through experiments and educational activities (Hall-Wallace and Wallace 1996).

During the last two decades, across Europe, several educational projects in earth science were developed and are ongoing in a variety of situations and national contexts (Fig. 1), with the aim to disseminate meaningful information about earthquake risk and the actions which can be undertaken to reduce or mitigate its effects. Two educational approaches are generally followed (Bobbio and Zollo 2009).

The first one has an immediate impact, and it is strongly based on traditional communication supports such as booklets, brochures, websites, videos, large public seminars and conferences. The end users (students, teachers, large public), following a traditional approach without any experimental practice, generally have a passive role in front of the scientific communication messages. The knowledge about complex natural phenomena has to be acquired through the individual's willingness and understanding capacity.

The alternative approach is instead grounded on advanced technologies by the implementation of seismic wave recording instruments and use of web-oriented and accessible data analysis tools, which provide a direct access to the seismological laboratory practice. In this case, the end user has an active role in the knowledge process by observing, experimenting and measuring the natural phenomena, following modern approaches of interactive science communication which are now pursued by scientific museums such as the Exploratorium in San Francisco, California.

Both approaches are useful and effective in communicating earthquake science and related risks. The first one is certainly more manageable, easy to use in particular for applicants who are not familiar with scientific and experimental approaches. It is generally made appealing by the use of an eye-catching look, which is more adapted to a generic public mostly composed by very young pupils, whose attention is captured by nice images and graphic applets, the use of which does not require any further scientific explanation.

The other approach is obviously addressed to a more ‘specialised’ public, e.g. high school students and teachers, and well-trained and guided museum visitors, since it requires a deeper involvement and an active participation of the user in the scientific knowledge process. The game is here to make students and teachers the main actors of the scientific experience, by guiding them along the path of laboratory research practice, based on seismogram observation, measurement, analysis and interpretation.

During the last two decades, this innovative approach has been implemented and carried out in a number of schools, research centres and scientific museums from several European countries, after the pioneering experience of the Princeton Earth Physics Project (PEPP) in the USA (Steinberg and Phinney 2000; Nolet 1993). It uses advanced technologies for seismic wave recording and visualisation or more basic seismic recording instruments and introduces pupils to the analysis of seismograms, measurements of earthquake source properties and the study of seismic wave propagation in the Earth through web-oriented, easy-to-use analysis tools. The ambitious target is to make students, teachers and the general public have an active role in the knowledge process and training them by adopting the ‘inquiry-based science education (IBSE)’ modern approach of science communication (Banchi and Bell 2008).

Excellent tools and resources for classroom-based experiments which link well with national curricula have been produced by individual groups through national and European funded projects.

- In France, the educational programme ‘Sismos à l’Ecole’ focused on seismic risk education through a scientific/technological approach. Sixty French schools take part of the education seismology network, by hosting and managing a seismic station, specifically designed and realised for the school. It is a worldwide network with about 12 stations situated in French schools outside France (e.g. China, Australia, EU, Ecuador). Small and large earthquake signals are recorded by French school seismometers, and data are accessible online in real time through a dedicated website (http://www.edusismo.org). In each high school, the teacher’s teams are helped by an academic researcher from a close-by university laboratory, acting as a science facilitator.
- In Italy, about 300 students and 10 teachers in different disciplines (physics, natural sciences, informatics and electronics) from 6 southern Italy, high schools

have been fully involved in yearly based EduSeis (Educational Seismology) scholar programmes. During the EduSeis project, the science museum Città della Scienza built and implemented a school lab (SISMALAB), an interactive exhibit for museum visitors and high school classes. In this lab, students and visitors had the possibility to perform seismological data analyses using the EduSeis network database to access data from a real-time seismic station. In 2010, the project restarted in the framework of the seismology@school initiative of the EU project NERA (Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation, http://www.nera-eu.org/) with the initial implementation of five stations in high schools of the Campania region. The project will fully integrate into the real-time, southern Italy ISNet network for active fault monitoring and early warning applications (www.sismoscholar.it). Two of these schools will also be involved in a pilot project for earthquake early warning testing and training in the framework of the European Union project REAKT (Strategies and tools for Real time EArthquake risK reducTion).

- In the UK, since 2005 the school seismology project (UKSSP) has developed a nationwide educational seismology community where teachers and students run simple and inexpensive seismometer systems to be used for detecting earthquake signals, are trained in data analysis and perform several activities on basic physics and earthquake recording instruments. The project has two aims: to make science more interesting for students aged 11–16 and to increase the awareness of geosciences as a potential career and academic discipline amongst students aged 11–18. For these purposes, two distinct requirements for the project were identified: a set of classroom activities to teach students about some basic physics principles but which all had earthquakes as a unifying theme and a simple, inexpensive seismometer system to detect earthquake signals and also to explain some basic physics about how seismometer works.

  The underlying idea of the UK School Seismology Project is doing 'real science with real data' enabling schools to detect and analyse signals from large earthquakes happening anywhere in the world.
- In Switzerland, the programme Seismo@School (http://www.seismoatschool.ethz.ch) started in 2008 and provides an integrated platform for seismic data and general information diffusion, including data from stations installed in Swiss schools and from the broadband national SED (Der Schweizerische Erdbebendienst: The Swiss Seismological Service) network. The Seismo@School platform is a general resource centre for education activities in seismology, which distributes a rich collection of earthquake data, bibliographies, movies, various educational materials and software for seismic data analysis.

These and other European initiatives on educational seismology will merge in the EU project NERA where a specific work package is dedicated to networking school seismology programmes. The ambitious target of the project is to build a dedicated facility for a European-wide school seismology programme, which allows for both the efficient sharing of data across national programmes and the scientific use of the data collected by this distributed infrastructure.

2 Instrumental Development and Projects

Seismology can be used in schools in many different ways. It can be used to teach students about earthquakes and hazards in their local environment, about wave propagation at large planetary scales or about damping and resonance phenomena at local site scales. Academic seismologists have used schools as locations for research grade seismometers in global tomography studies, and primary school teachers have constructed wobbly towers from jelly (Fig. 2). There is no single or correct method of using seismology in schools, rather a broad spectrum of approaches, each driven by different aims and objectives but linked by the enduring power that earthquakes have to capture students' attention and imagination.

Observational seismology in schools has developed along two parallel and complementary strands, one driven by research seismology and one driven by inquiry-based science education. These are reflected in the instrumentation as well as in the educational aims and funding streams of various seismology projects around the world.

In 1979, *Scientific American* published an article describing a simple design for a horizontal pendulum mechanical seismometer made by James Lehman of Virginia (Walker 1979). This seismometer used a garden gate suspension mechanism to create a horizontal pendulum with a natural oscillation period of 12–18 s. The garden gate suspension system for a horizontal seismometer dates back over a 100 years to seismometers developed by John Milne when he was professor of mining and geology in Tokyo. These early seismometers (4a) recorded ground displacement directly using pen and paper charts or by light beams on photographic film (Milne 1888). The addition of electromagnetic sensors detecting ground

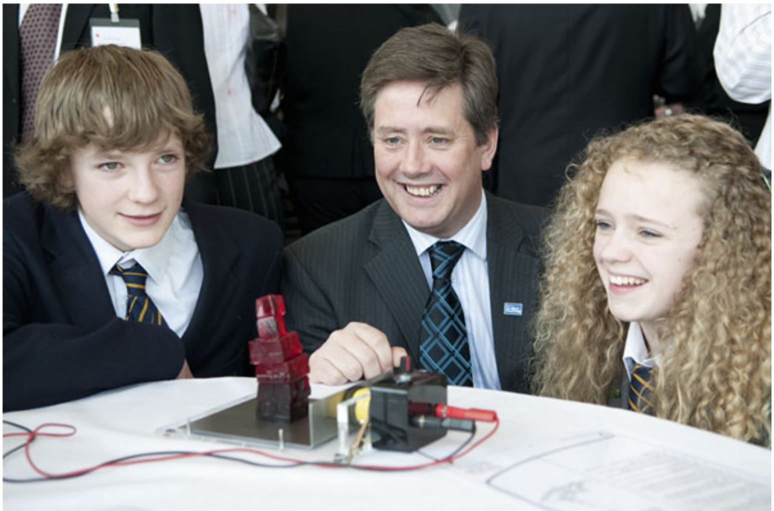

Fig. 2 Jelly towers are used to show how buildings respond to being shaken

velocity enables signals to be easily amplified and filtered. Variations of this simple design have been built by many amateur seismologists, including Stewart Bullen, a science teacher from Hereford in the UK, who built and ran his own seismic station from the late 1980s (Bullen 1998).

In 1994, seismologist Guust Nolet from Princeton University, USA, set up a school seismology network designed to make use of school-based seismometers to record research quality data for tomographic studies. He set up the Princeton Earth Physics Project (PEPP) (Nolet 1993) and worked with instrument manufacturer Guralp Systems to develop a low-cost broadband seismometer system. The result was the Guralp CMG-PEPP seismometer, a force-feedback vertical component seismometer with a flat frequency response in the band 30 s–10 Hz, a 24-bit digitiser and GPS timing system (Fig. 4c).

The idea of using schools as relatively inexpensive sites to locate professional seismometer systems is attractive to seismologists. Unfortunately, the project never really achieved the seismologist's dream of installing thousands of additional research quality stations; there are now only 10–20 school stations in the USA running PEPP seismometers. The advent of large portable arrays run by groups such as PASSCAL (Program for Array Seismic Studies of the Continental Lithosphere) in the USA and GFZ (GeoForschungsZentrum: German Research Centre for Geosciences) and SEIS-UK (the seismic node of the NERC: Natural Environment Research Council) in Europe meant that seismologists could run targeted experiments using hundreds of high-quality stations over areas of special geological interest for fixed periods of time.

In the USA the idea of using a simple mechanical seismometer led to the development of a vertical seismometer, the AS-1 (Fig. 4d). This instrument originally designed in 2000 and built by Jeff Batten was championed by the seismologists John Lahr of the USGS (United States Geological Survey) and Larry Braille from Purdue University.

The AS-1 design proved popular with teachers because of its simple and visually accessible design. This instrument is now the mainstay of a national seismographs-in-school programme in the USA with over 200 schools using the instrument. The US schools network is now supported by IRIS (Incorporated Research Institutions for Seismology), and Alan Jones of Binghamton University, USA, wrote a data-logging and analysis programme for this instrument called AmaSeis (www.iris.edu/hq/sis).

In Europe, school seismology was given a boost in 2000 by an EU-funded programme, EduSeis, which is the acronym for Educational Seismology. This project included the development and distribution of a large number of classroom activities to run alongside the school seismometer stations. In addition to the Guralp PEPP sensor, the European network also used geophone-based seismometers which artificially boost the low frequency response of a standard 4.5 Hz geophone to produce a flat frequency response between 20 s and 50 Hz. With the end of the EU funding, the French schools network managed to continue with national funding and now comprises over 50 schools running semi-professional stations equipped with a data-logger SAGE (Système d'Acquisition Générique pour les écoles), developed in order to realise a robust and extremely simple data acquisition system to be installed in a school (Fig. 4e, f). The digitiser-recorder box is connected to the local computer network of the school using either Ethernet or wireless connection. Each seismological station records in continuous mode the ground motion with a

Fig. 3 The history of instrument deployment in all countries involved in educational seismology projects

Table 1 A list of seismological equipment with its characteristic

	Guralp PEPP force-feedback	Extended geophone	AS-1 mechanical	SEP mechanical
Quality	Very high	High	Very low	Low
Component	Vertical	Triaxial	Vertical	Horizontal
Bandwidth	30 s–20 Hz	20 s–50 Hz	2 s–3 Hz	20 s–10 Hz
Digitiser	24bit	24bit	12bit	16bit
Timing	GPS	GPS	PC clock	PC clock
Simplicity	Very complex	Complex	Very simple	Very simple
Cost	>$1,000 per component	>$1,000 per component	~$500	~$500
Visual appeal	Poor (black box)	Poor (black box)	Good	Good

sampling frequency of 50–100 Hz. Broadband seismometers ensure a high sensitivity in a large frequency band. A GPS unit allows the data to be synchronised with universal time. The timeline of school seismology instrumentation is shown in Fig. 3.

The seismological equipments installed in the different European countries are listed in Table 1, and a fairly complete representation of the instrumentation used in schools is shown in Fig. 4.

The inventory realised in the frame of NERA project on the current status of seismic stations in schools in Europe revealed many 'wrecks' of formerly seismic stations, web pages and e-learning experiments. However, it also pointed out the presence of many operating stations, the data of which are currently available or can be easily included in a comprehensive database.

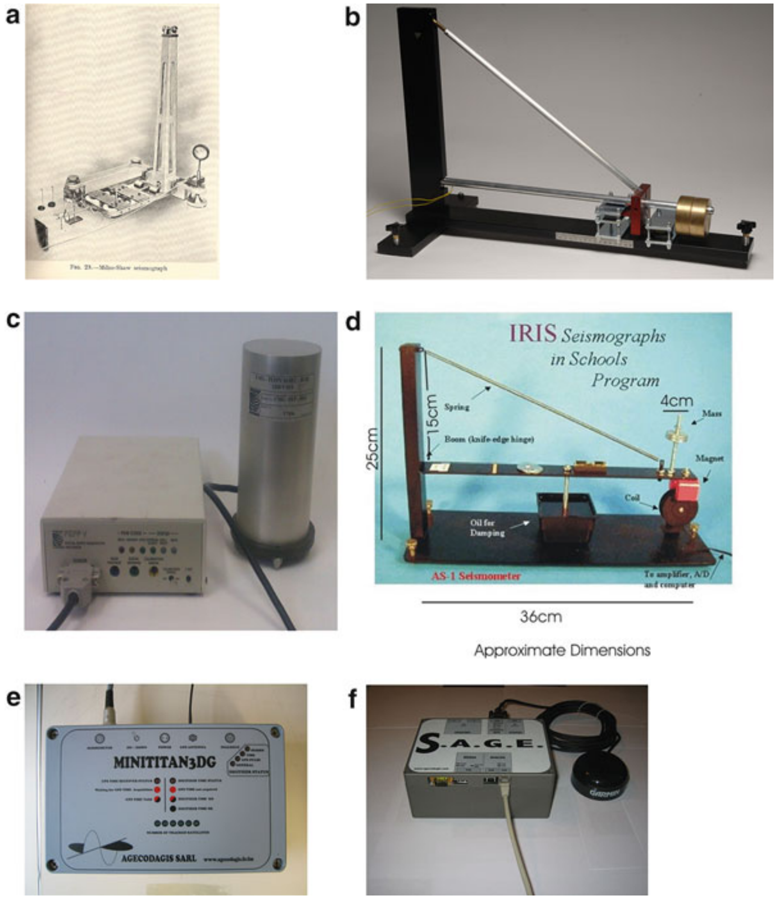

Fig. 4 (**a**–**d**): An overview of different school seismological instrumentation: (**a**) nineteenth-century Milne Seismometer, (**b**) 2006 UK SEP school seismometer, (**c**) 1996 Guralp PEPP seismometer, (**d**) 2000 AS-1 seismometer and (**f**) Agecodagis SAGE seismic system

At a first glance, the map of the seismic stations operating in schools in Europe shows a clear unbalancing of their number in the western region with respect to the eastern side (Fig. 5).

3 Implementation, Outcomes and Evaluation

3.1 France

The network ‘Sismos à l’Ecole’ numbers around 60 stations installed in metropolitan France, the overseas departments and territories and few French high schools abroad. It is the outgrowth of an experiment conducted in the south of France aimed at

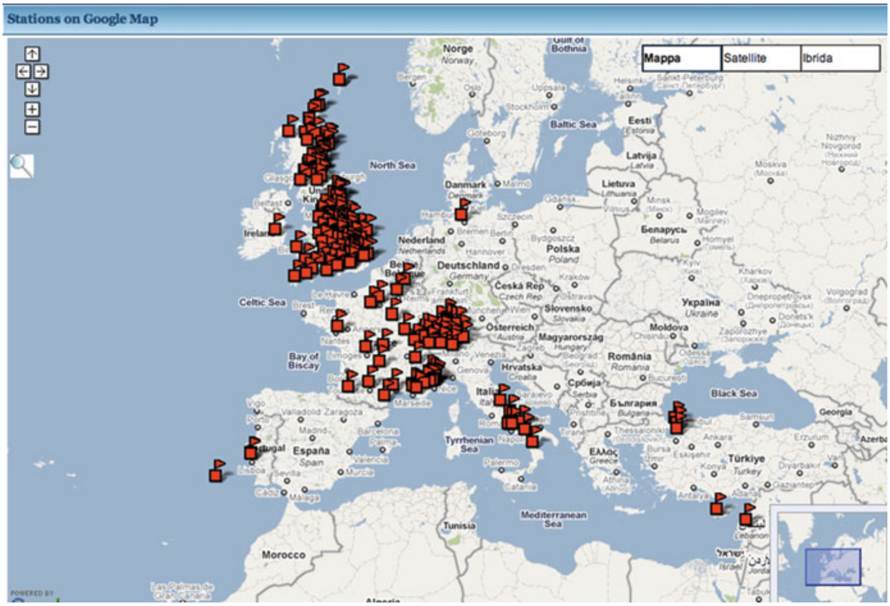

Fig. 5 Distribution of seismic stations in Europe

studying the feasibility and the pedagogical interest of installing a seismometer within a school. The project was first implemented over a period of 10 years (1996–2006) and involved a close partnership between the Conseil Général 06, the Rectorat of Nice district and the Géoazur research lab (Virieux 2000). The results from the deployment of five stations showed that it was possible to record high-quality signals in a school environment. Teachers revealed a number of positive points from this experience: the students were enthusiastic to perform measurements, the online database was easy to access and use, the students were encouraged to work independently by taking responsibility for the management of the seismic station, and finally, the experience demonstrated the importance of regular interactions between school teachers, student and scientists from the closest Géoazur laboratory in French Riviera. Since 2006, the programme ‘Sismos à l’Ecole’, which is part of the broader project ‘Sciences à l’Ecole’ supported by the French ministry of education, has extended the educational seismological network throughout the country. Following a call for proposal, new schools were selected according to the quality of their pedagogical projects in order to build an active network. Now, 60 stations record in continuous mode the ground motions in French schools, either in metropolitan France or abroad (Fig. 6a). Each school is linked with a volunteer seismologist from a nearby university laboratory. The seismologist must build a relationship of trust with the educational team that will call on him (or her) to address technical or scientific issues and also to occasionally participate to activities in the classroom. The network’s success is largely due to the dynamism and cohesion of its teams.

Fig. 6 (**a**) Map of the 60 real-time seismological stations of the French 'Sismos à l'Ecole' network (Data from all stations are accessible freely via the Internet through the website www.edusismo.org), (**b**) Building scientific know-how and some examples of seismo-tools. The seismo-cookbook

c

Fig. 6 (continued) gathers activities and experiments that can be made by students from 11 to 18 years old. A toolbox has been constructed to help teachers and scientist to present different parts of seismology, (**c**) The educational session in ESC (European Seismological Commission) 2010 meeting in Montpellier. Students, teachers and scientists sharing experiences

The school curriculum has several important aspects, placing large emphasis on new communication technologies: the scientific content (instrumentation, earth dynamics and geophysics), the educational dimension (making aware about seismic risk) and the regional, national and international dimensions (networking schools). The students observe, measure, compute and discover in order to understand better natural phenomena (Fig. 6b).

Within the framework of courses in earth and life sciences, physics, technology and geography, there are various pedagogical suggestions proposed for the curricula of French high schools concerning the measurement of a physical parameter, the knowledge of the geological environment, the understanding of the complex mechanisms of the internal geodynamics and the notion of environmental risk.

In all these activities, transversal approaches are encouraged, measurement, observation, model building and investigative thinking, to grasp the scientific concepts related to geosciences and physics. This building of scientific know-how is essential to education, information and awareness on environmental risks.

The teachers (about 110) and researchers (about 20) who are involved in the 'Sismos à l'Ecole' network follow a regular training programme and attend meetings, one each year or every 2 years. They have proposed, coherently with the objectives of French Ministry of Education, several scientific topics that can be developed in the classrooms with students.

The topic dealing with ‘sensors’ is one of the most important. The measurements of a physical quantity by a sensor (e.g. the measurement of ground motion versus time) can be investigated, using sensors from the seismological station or sensors developed by students. Several aspects of basic science are tackled, including the definition of frequency, bandwidth, fidelity, repeatability and the robustness related to the linear oscillator behind the sensor.

The topic dealing with ‘data’ arises naturally. The analysis of recorded signals leads to various activities, including activities on waves, a key concept in the modern society as radio, TV and Internet use electromagnetic waves massively. Travel times, wave speed and source location through triangulation are typical concepts a student can easily manage without getting into sophisticated mathematical tools.

The ‘earth sciences’ topic is obviously central to teaching of natural sciences. Possible activities include geographical mapping through the presentation of data collected from the schools, the discussion of seismic hazard either on a global scale or a local scale and the presentation of different seismic signatures such as the Benioff subduction zones or the Moho discontinuity separating the Earth crust from the mantle.

The ‘risk’ and ‘hazard’ topics come naturally after these various speculations or analyses. Based on seismic records, students can illustrate through practical models the notion of intensity, building resonance, earthquake-proof rules of construction and the induced effects of a tsunami on coastal zones. With many national initiatives, this topic will become more and more important in educational training.

All these practical activities have been brought together in a single workbook and some models (Berenguer et al. 2009a, b).

3.2 The UK

In 2005, inspired by the success of school seismology networks set up and running in various US states using AS-1 and Guralp PEPP seismometers, the UK started work on a school seismology project (Fig. 7) (Denton 2009).

The UK project arose out of a need to improve participation rates in school sciences, especially physics, once students were able to choose subjects to study (and which ones to drop) at age 16. In the previous decade, the number of students studying physics had dropped by 50 %. Universities running geosciences degree courses at undergraduate or postgraduate levels were struggling to recruit good students to their courses, and the major employers of geosciences graduates in the UK were suffering recruitment problems as a consequence.

Initial discussions with small focus groups of ten secondary school science teachers at a workshop organised by Leicester University led to a number of conclusions: (1) the use of practical observational seismology in a UK school environment was thought to be an excellent context for teaching about a wide range of basic science topics. (2) Given the choice between a research quality seismometer in a ‘black box’ enclosure and a simple mechanical sensor with a visually open design, the teachers all preferred the simple mechanical design.

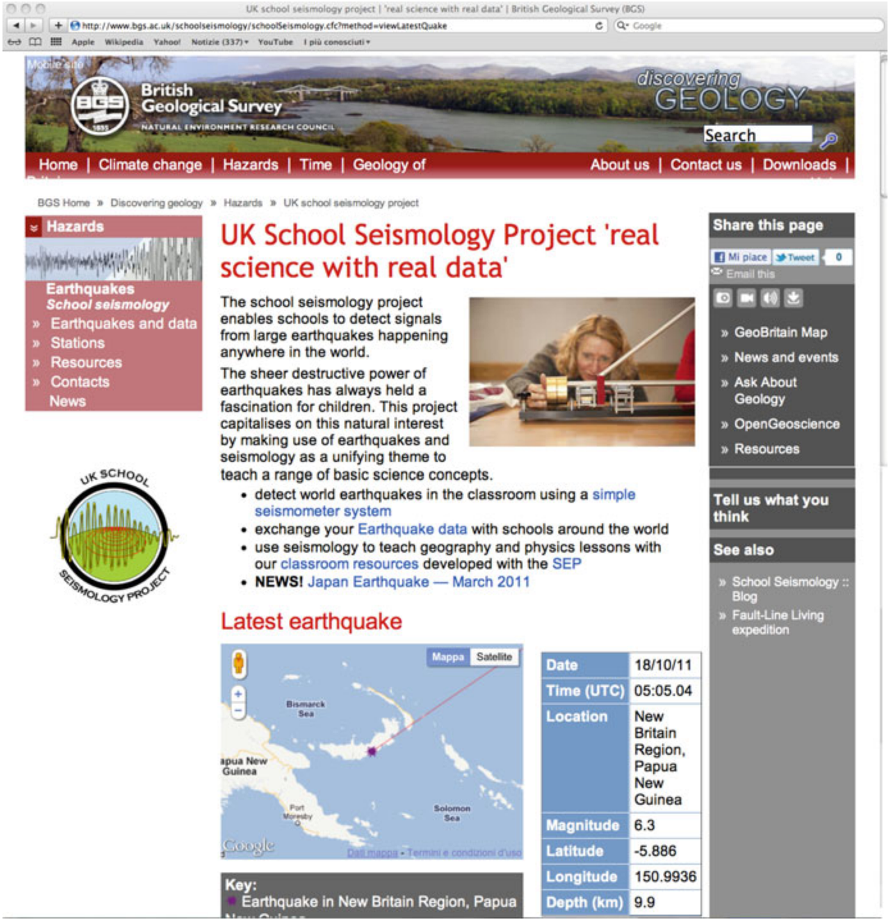

Fig. 7 The website of the UK school seismology project http://www.bgs.ac.uk/schoolseismology

Each year in the UK, a seismometer station located in an urban environment is likely to detect above background noise less than ten local earthquake signals (from the UK or Europe) but over 50 teleseismic earthquakes, mostly from the Pacific rim. In order to be able to detect the large-amplitude surface waves with peak frequencies around 0.05 Hz from these teleseismic events, a simple mechanical seismometer needs to have a natural period of 20 s or longer.

The UK school seismology instrument was finally chosen as to be a version of the garden gate suspension horizontal pendulum system, designed and manufactured by engineers from the Science Enhancement Programme SEP (www.sep.org.uk), a charity-funded organisation dedicated to improving science education in schools.

The SEP school seismometer system (complete with amplifier/digitiser electronics package) was designed to be compatible with the existing AmaSeis seismic data-logging and analysis software and was launched in 2007 together with a tried and tested set of classroom science activities that all had seismology and earthquakes as a linking theme (Denton 2008). The British Geological Survey manages the UK school seismology project (www.bgs.ac.uk/ssp) by promoting the project to teachers and running training workshops in how to use the resources in partnership with university earth science departments around the country (Imperial, Leicester, Keele, Leeds, Plymouth, Bristol, Liverpool, Derby, UCL, Royal Holloway, Portsmouth, Edinburgh, Aberdeen, Cardiff).

3.3 Italy

Following the successful experience in the USA of the Princeton Earth Physics Project (PEPP) in 1996, Italy installed the first seismic station of the EduSeis project 'MSNI' (*M*useo della *S*cienza *N*apoli *I*talia) at the Science Centre 'Città della Scienza' in joint cooperation with the University of Naples 'Federico II'. In Italy, from 1997 to 2002, more than ten EduSeis stations were installed in high schools and at research centres in central and southern Italy, in particular at the Mt. Vesuvius volcano landscapes (Bobbio and Zollo 2000). The seismic stations were installed inside buildings, with the sensor preferably deployed at a ground or underground level while the acquisition PC was hosted in the informatics lab.

All the elements of the station were specifically designed for educational purposes and operating by the students and teachers themselves. The EduSeis network was made up of seismic stations that may record local, regional and world seismic events. The seismic stations are equipped with different acquisition systems and sensors used as a standard in scientific/monitoring seismic networks.

Special software applications have been conceived to make them easy for pupils to work on seismological data. Seismic recordings can be visualised and analysed with the Java SeisGram2K software developed by A. Lomax (www.alomax.net). With this applet, the signal can be zoomed and displayed together with the records from several other stations. In addition, different seismic wave times can be picked, and different band-pass filters are available to improve the seismogram analysis.

The basic idea of the EduSeis project was to use a network of seismic stations installed in high schools and related activities of data analysis as an efficient and pervasive tool for teaching, learning and informing about the earthquake origin, its destructive effect on the environment and the actions needed to mitigate seismic risk (Cantore et al. 2003).

Within this framework new approaches were experimented for providing information on seismology and seismic risk addressed to the general public and to high school audiences. These were realised through an interactive seismological lab (SISMALAB) operated and maintained by the scientific museum 'Città della Scienza' in Naples and through an *e-learning* environment in a high school located close to the Mt. Vesuvius volcano.

SISMALAB was a school lab and interactive exhibit (about 30 m^2), equipped with six multimedia graphic stations and an adjacent meeting point room for real-time teaching/learning activities for museum visitors and high school classes (Fig. 8a). Here people can experiment with seismological data analysis and learn about earthquake origins and occurrences, volcanic eruptions and earth sciences in general. A carnet of activities designed for the students of secondary and high school were specifically created for SISMALAB, thanks to a permanent staff formed by school teachers, museum personnel and young researchers from the University of Naples. The SISMALAB activities were differentiated by age for groups of students and visitors. Each group was involved in using software for processing seismic data. This experience revealed to be SISMALAB, an efficient tool to raise curiosity and stimulate students to ask questions and work directly on seismological data recorded at the different stations installed in schools (Cantore et al. 2004).

In the framework of this initiative, two related editorial activities started aimed at the diffusion of the EduSeis project: an information booklet entitled 'Earthquakes – How, where, when, why…' and a bimonthly electronic newsletter (Cantore et al. 2005).

The e-learning model experimented during the project was built on the EduSeis concepts and educational materials and based on the computer-supported collaborative learning (CSCL) that is an innovative method for teaching and learning which adopts the modern information and communication technologies. This kind of learning is characterised by the sharing and construction of knowledge amongst participants using technology as their primary means of communication or as a common resource (Stahl et al. 2006). The EduSeis educational activities (earthquake location, magnitude estimate, seismogram analysis, etc.) which are mostly based on web and net communication tools are suitable for this kind of experimentation. Ten teachers from different disciplines and 50 students of technical high school I.T.I.S. 'Majorana' (Naples) were involved in a cooperative e-learning experiment, using an informatics platform and the *jigsaw* method (Clarke 1994), in which students worked in small groups (communities) where each member evolved gradually from a fellow learner to a teacher and finally to a 'scientist' (Fig. 8b) (Bobbio et al. 2007). The learning process was assisted and supervised by teachers. The evaluation of experiment results provided useful insights on the contents and the educational value of EduSeis modules and activities.

In Italy, another project was carried out in the framework of the educational activities on earthquakes: EDURISK (EDUcation to RISK) (Camassi 2006; Solarino 2009). Although the targets and goals are very similar to the EduSeis project, the activities included were different and diversified in ways and forms of implementation. The EDURISK project is currently designed for the whole range of students' ages from primary to high school. It carries out a wide variety of activities, ranging from exhibitions to lessons in schools and visits to the National Earthquake Centre or museums run by INGV (Istituto Nazionale di Geofisica e Vulcanologia). During almost two decades of activity, the project has edited and printed many books and produced several multimedia items that are specifically designed to foster, nurture and enhance knowledge. The goal is to either explain the science behind the natural phenomena or to increase the preparedness of future citizens towards them. However, the most important activity is developed for and with the help of teachers. Instead of directly informing single groups of students, the researchers of EDURISK staff involved teachers. In practice, the teachers joining the project undertake to fit

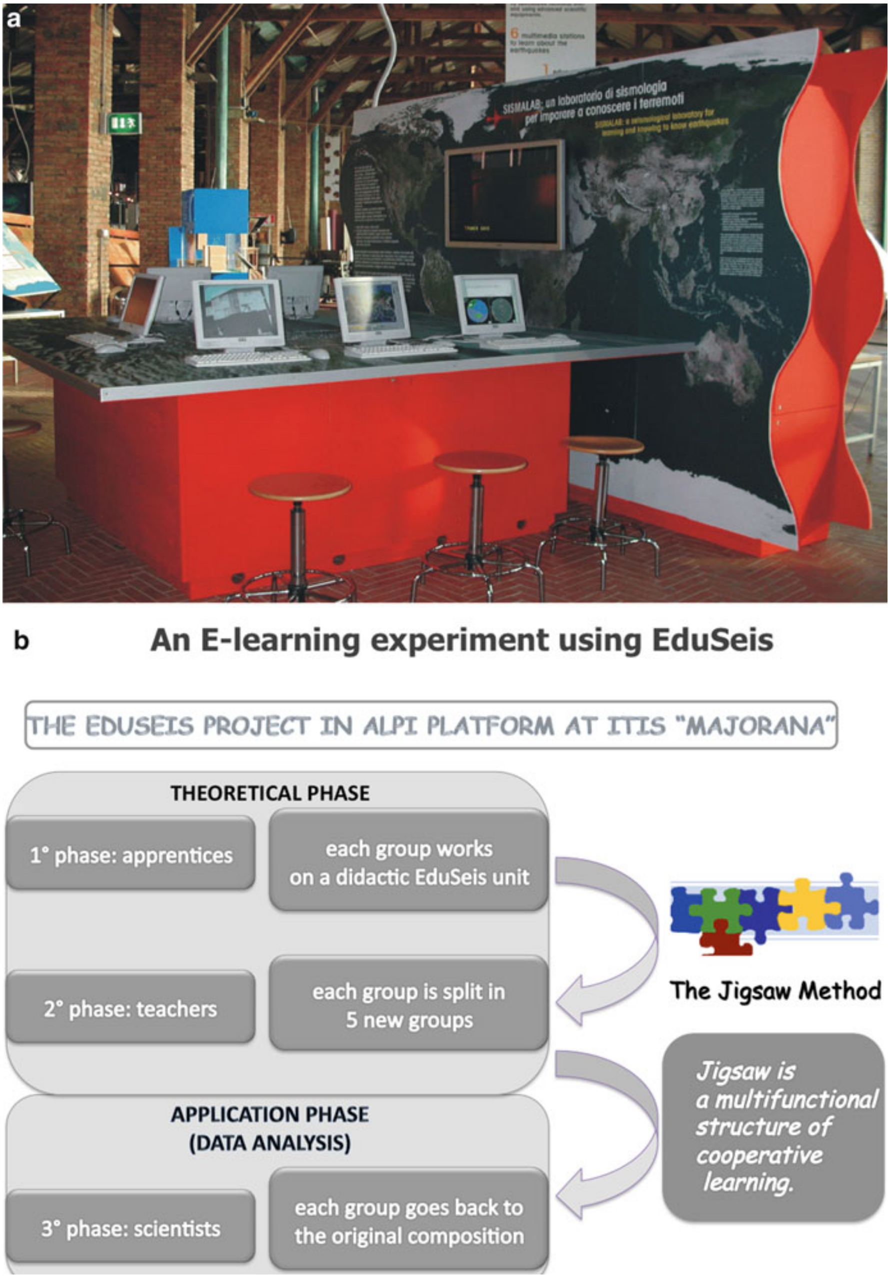

Fig. 8 (**a**) The SISMALAB at the Science Center of Città della Scienza in Naples, (**b**) A scheme of the e-learning experimentation at ITIS Majorana (Somma Vesuviana, Naples). In the first phase, each group became the experts of a topic on seismology; in the second phase, the groups were split and each student could be a teachers for the members of their new group; in the last phase, the original groups were reassembled and the students, having acquired a deeper knowledge on seismology, were considered as 'scientists'

the EDURISK prototypes within their curricular activities for at least one academic year, at the end of which they assess their effectiveness, suggest alterations/improvements and provide additional feedback.

3.4 Switzerland

Through seismology, the programme *Seismo@School* tries to make significant contributions to science education in the understanding of the Earth system and complexity.

The *Seismo@School* network consists of seven seismic stations installed at schools across Switzerland. This number has been increased to 15 at the end of 2011. The first stations of the SED (Swiss Seismological Service) were equipped with short period seismometers that provide high-quality waveform data for the regional seismicity. Future stations will be equipped with standard strong-motion sensors, which are routinely used by the SED national network. They provide at the same time good data quality for the school network and valuable additions to the national monitoring efforts of SED. Stations are installed in quiet basement rooms in school, to avoid as much as possible disturbances induced by human activities.

The school network database contains the seismic waveforms recorded by 12 stations of the Swiss national seismic network operated by the SED to allow comprehensive analysis of the recorded seismic events. For educational activities, schools also make use of other stations like the one component SEP seismometer system or the Stanford accelerometer, Quake-Catcher Network Sensor (http://qcn.stanford.edu/sensor/), which are very useful for classroom activities.

The cornerstone of the educational activities within *Seismo@School* is the project website (www.seismoatschool.ethz.ch). This open-access website provides access to both real-time streams and data for selected seismic events. The website also makes available a rich set of software packages for data display and analysis, specifically developed for schools' needs. Analysis capabilities of the software include travel time calculations, phase picking (onset determination), earthquake location and location process visualisation, amongst others.

Background and in-depth information on the school project and on specific scientific topics are also available from the website as well as all educational materials (books, classroom activity suggestions).

The activities in schools range from participation in the installation and operation of the seismic school stations to classroom experiments involving students of different ages and levels. The educational material contains books, posters, experiments and an earthquake simulator. As seismology is not covered in standard education of teachers, and earthquakes are not usually part of the school curricula, the SED developed a training programme for teachers comprising three steps. The first step '*Four days formation at school*' aims at providing an in-depth explanation and training on the seismic station installed at the school and a familiarisation with the tools and data available on the Seismo@School website, to foster enhancement of seismology and earth science education in schools. The second step involves teachers' workshops at ETHZ (*E*idgenössische *T*echnische *H*ochschule *Z*ürich: Swiss Federal Institute of Technology Zurich). These workshops comprise lectures by SED researchers on seismological topics, combined with visits to the *focus*Terra exhibition and the earthquake simulator. They are organised to provide professional development experiences for educators. Teachers will become active participants learning through demonstrations, computer modelling and hands-on activities. For example, in the area of seismology, teachers are trained to handle the seismometer instructional materials, to access seismic data via the web server and to access and use all the programmes available to explore and analyse the data. As a last step, national and international seminars are organised to facilitate good connection between teachers (teachers' network around Switzerland and Europe) and to promote exchanges with researchers. The experience and feedback during these events have confirmed that such conferences and workshops are really successful and represent the best way to share experiments and knowledge (Fig. 9a–c).

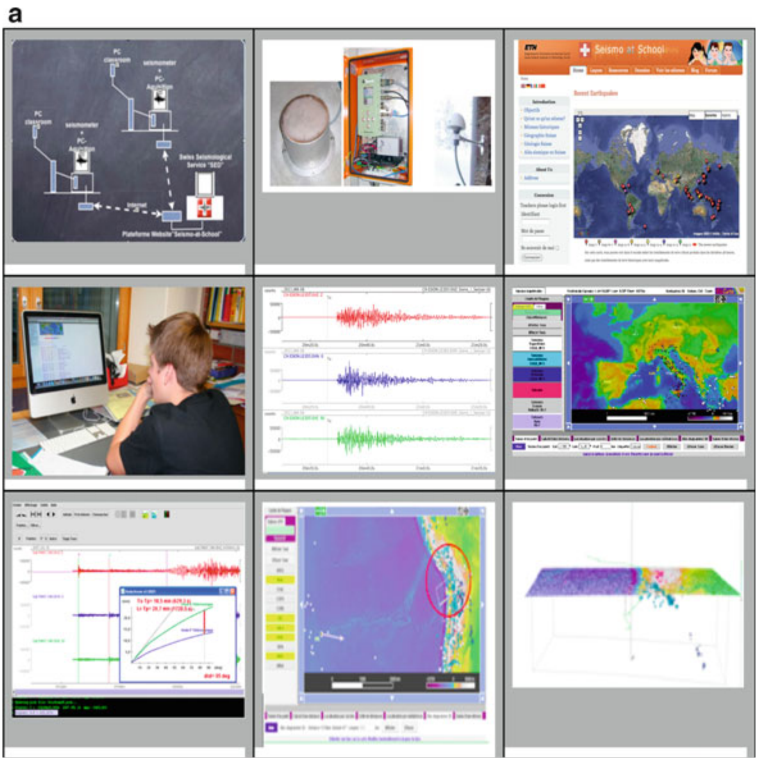

Fig. 9 (**a**) Scheme of the school network in Switzerland. Example of seismometer and GPS installed in school. Website Seismo@School connection for students working with data and softwares developed for them, (**b**) Preparation and installation of SEP seismometer by students, during physics lecture, (**c**) Activities and booklet developed for schools, earthquake simulator room, conference for schools in Zürich, training the teachers, students' exhibition in national and international conferences

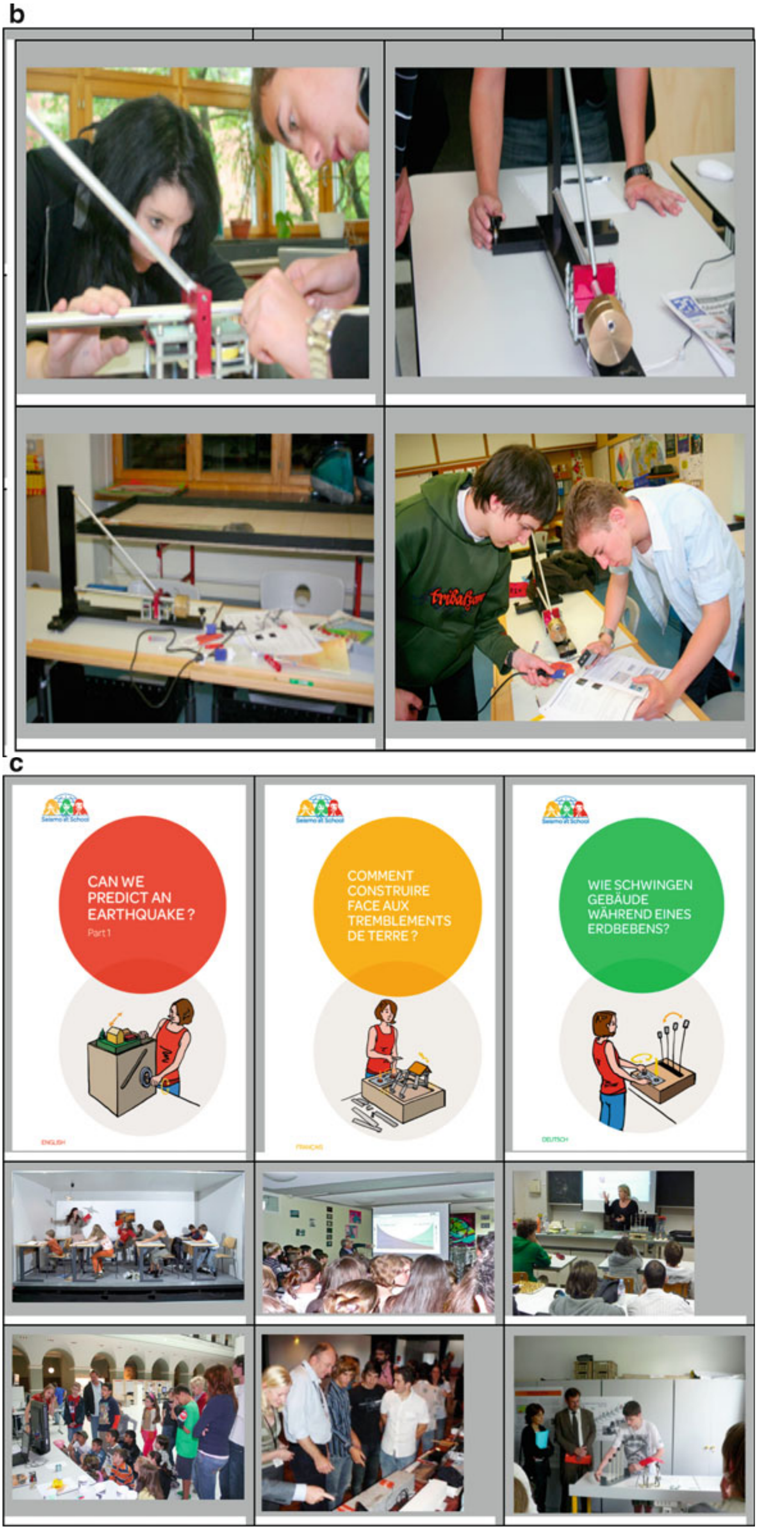

Fig. 9 (continued)

3.5 Cooperative and Interregional Educational Activities in Seismology

Unlike the pioneer initiatives, which were involving single countries, the most recent educational projects share experiences, skills and data amongst several nations. The exchange is mainly supported by and operated through the availability of fast and reliable Internet connections, but often experiences and common activities are designed in dedicated meetings where teachers and students from different countries gather and discuss.

The project O3E (Observation of the Environment for Education purposes at School) (Berenguer et al. 2011), recently concluded after 2 years of activity, established a network of schools amongst the participating countries of France, Italy and Switzerland. The project, financed by the EU under the ALCOTRA programme, was born to promote a responsible behaviour of citizens against natural hazards

The aims include:

1. Promoting the applied sciences and new technologies
2. Gathering students, teachers and scientists in a network developing the sense of the autonomy and the responsibility of choices in young people
3. Reinforcing and developing relationships with regional partners of the educational and university fields
4. Supporting a rational awareness for the prevention of the natural risks that can make the difference during the event in terms of safety

About 30 schools located in the territories included in the ALCOTRA programme were equipped with seismometers and/or weather stations of educational vocation. Teachers and students were given the responsibility of the data collection and instrument maintenance. Data were shared with the entire educational community through dedicated servers on a common web page (http://o3e.geoazur.eu/) and served as the basis of numerous experiments and activities.

During the first stage, researchers and technicians, both from academic and nonacademic institutions, provided assistance for the installation of the instruments, to set up the data transfer and gave introductory lectures about the scientific and technical aspects of the project. A few multimedia and printed products were prepared and distributed within the project, in some cases to be used as a guide for common experiments. Finally, some digital documents and software were made available in the 'documents' section of the web page.

However, soon schools were let free to design and conduct their own experiences, which are of course finely tuned to the actual environment and hazards of the country and territory. The results of these activities have been discussed in a final, comprehensive meeting (http://ftpaster2.unice.fr/o3e/images_docs/110204_104630-Actes_complets.pdf).

There are many outcomes of the project that deserve mention. In most cases they are directly linked to the philosophy that leads the project and are innovative with respect to many previous other educational programmes. In fact, the presence and maintenance of an instrument introduce problems and needs to which only professional are used to; adapting school life to these aspects introduces in new attitudes.

Amongst the main consequences, students and teachers were required to check the discrepancies between the real data and the information disseminated by the media, developing and improving their critical skills. The need for good and reliable data made them understand the difficulties behind such a task and especially the errors and uncertainties on measurements and models. Finally, the students could identify and understand the main natural hazards of the places where they lived and their potential impact. All these aspects may have concurred to form citizen better prepared to face emergencies and able to disseminate correct and sound information.

4 Implication for Wider Practice and Conclusions

The main initiatives to introduce seismology in European schools and use it as a vehicle for a multidisciplinary teaching about earthquakes and Earth dynamics in general have now been active for more than two decades. At the same time, teachers have been able to estimate the contribution of such actions in their practice of teaching.

Now, it is possible to draw up a first assessment of these actions.

A recent survey on the French school network collected the opinion of about 50 teachers and educators on the programme led since 2006 in France (http://www.edusismo.org/docs/news/120103_125618/resodusismo_2011.04.pdf).

The general opinion is that, in 10 years, the set-up seismological equipment and analysis tools (seismometer, data online, models) quickly have become established in the landscape of the classroom and are more and more used for new practices of teaching natural sciences in high schools. They are also the mainspring in the creation of scientific labs where students lead investigation projects by themselves.

In earthquake-prone areas, seismological experimentation at schools is also a way to increase the awareness on seismic risk and earthquake effects of students and, through them, of their parents. This is the case in southern Italy, where earthquakes and volcanic eruptions represent the most relevant natural hazards hanging dangerously over the population. The experience of educational seismology at the Science Centre ‘Città della Scienza’ in Naples is exemplary. Thousands of elementary and high school students have visited the earth science section of the museum, having the opportunity to play with and learn from seismological tools running on the interactive exhibits in the museum and using the SISMALAB laboratory, a multimedia, open space for educational activities in seismology. The successful participation of students and museum visitors clearly indicates that innovative teaching approaches based on web and net communication tools are well adapted to communicate and inform about natural hazards.

Another key point is the scientific support of researchers and the need to establish strong links between teachers and researchers. The implementation of educational seismology projects in schools has been carried out in the framework of joint projects where schools, research centres and universities participate in partnership. The role

Table 2 A list of strong points and weak points in the application of educational projects in the school system

Strong points	Weak points
'Learning by doing' approach applied to earthquake and wave propagation phenomena	Difficulty to involve teachers at zero-cost, in extracurricular activities
Enhancing and stimulating the cooperative work	The management and maintenance of the seismic station needs a continuous effort and engagement
Making students acquainted with the seismological laboratory practice, data	Small flexibility to use school time and spaces and insufficient resources (informatics, tools, instrumentation)
The simplicity and cheapness of equipment has allowed its distribution to a very large number of schools, the overall aim being to change the perception of geosciences in schools across the country	With such a large number of schools, it is difficult to provide detailed one-one support for teachers with problems. The simplicity of the equipment means that the data cannot be used for scientific research

of researchers is to accompany and support teachers in their discovery, formal activity development and training on seismological tools. The collaboration between researchers and teachers on the development of seismological activities is crucial and demands for a continuous and mutual effort to immerse oneself in the shoes of the other, sharing the different languages, scientific backgrounds, levels and tools of scientific communication. The effective interaction between school and academia staff is the key for the success of these educational initiatives, and to establish a good, convivial and enthusiastic working team is likely the first but most important task of an educational project in geosciences. This is not always an easy task, since in most cases these activities are carried out by researchers and teachers on a voluntary basis not being part of school curricula or funded research programmes.

We should not neglect the problems and difficulties of the application of these educational projects in the school system, in particular the need for a big involvement of teachers and researchers. The main difficulties in the development of the projects are related to the teachers' involvement at zero-cost outside working hours, the small flexibility in school time and space and the insufficient scholastic resources (informatics, tools, lab instrumentation) (e.g. Table 2).

At any time and for any of the European experiences, the website is the central tool of the educational seismology programme, and a well-designed website strongly facilitates interactions and data/information diffusion. The website is the place where the screen of a school seismological station is displayed (simple link to the school seismometer) either to visualise the real-time recorded data or to access and analyse the archived data. The statistics of the French 'Sismos à l'Ecole' websites confirms this trend for Internet users (6,000 visitors per month access the French website). Teachers and students can also find and download hands-on educational activities or scientific documentation or other material to support the teaching of earth science and seismology in particular.

The publishing of the resources (seismograms, mappings, hands-on activities) demands particular care because it addresses the whole educational community: students, teachers and the general public. The website must be able to offer data quickly, simply, and in high-quality format. The elaboration of such sites still remains a big challenge.

The new vogue is to open the website to social media and blogs, transforming it from a static archive of information to a virtual place where users can debate, ask questions, comment, tweet and share photos, videos and educational experiences on earthquakes and their impact on the environment and society. This approach generalises the concept of an educational geoscience website making it an e-platform for science communication and multimedia data sharing, where researchers, teachers, students and education operators can interact and constantly be kept informed of ongoing activities and relevant events.

Finally, all of these ‘seismology at school’ initiatives rely on the concept of school networking. A collaborative network is created through the publication of data on the website, the organisation of training courses and the communication of actions led in different schools. Also, the exchange and publication of data collected by individual schools and shared through the Internet are essential.

The concept of ‘networking’ is intrinsic to the seismological observation: a complete description of seismic wave propagation or the determination of earthquake source parameters cannot leave out the use of many sensors, organised in a seismic network and deployed at different azimuths and distances from the source. This facilitates the process of ‘networking’ schools that are involved in an educational seismology project since the earthquake and the related seismic wave observations from a seismic sensor hosted in a school can (must) be shared to get the complete description and interpretation of the natural phenomenon. Examples include the process of locating an earthquake, which uses the P- and S-wave arrival times read at different stations to compute the event coordinates, depth and origin time or of estimating the subsoil apparent seismic velocity, needing measurements of arrival times from stations located at increasing distance from the source.

We can usefully wonder about the main directions to be followed, even to be developed, for future programmes of educational seismology. Trying to get the schools involved and actively participating in scientific projects that use data collected by school seismographic stations is the ambitious target of the next generation of ‘seismology at school’ programmes at a national and pan-European scale. This will require a special effort to improve the technological level of instruments deployed in schools in addition to setting up a network data management system resembling the professional ones used by seismological agencies. But it also demands a specific training activity for teachers and students to make them acquainted with the seismological laboratory practice on instrument maintenance, data control and validation, data analysis and modelling, a quantitative assessment of uncertainty and resolution.

The EU project NERA may be a possible answer for a new step in the national educational seismological programme in Europe (Table 3).

Table 3 A list of european seismological projects with corresponding websites

Projects	Website
NERA (*N*etwork of *E*uropean *R*esearch Infrastructures for Earthquake Risk *A*ssessment and Mitigation)	http://www.nera-eu.org
NERA WP8 (ITALY)	www.sismoscholar.it
EDURISK	http://www.edurisk.it
Seismos à l'École	http://www.edusismo.org
UK school seismology project	http://www.bgs.ac.uk/schoolseismology
Seismo@School	http://www.seismoatschool.ethz.ch
O3E (Observation of the Environment for Education purposes at School)	http://o3e.geoazur.eu/

It plans to share the data recorded by each school network, to share also the experiences of teachers and/or students. New computing tools are to be implemented to improve this interconnection of school seismic networks and programmes. Training workshops, gathering teachers from various countries (summer schools for teachers), will contribute to these exchanges. It is at the very last a desire of the teams involved to develop more contacts between schools in Europe.

Overview

Background and Motivation

– During the last two decades, across Europe, several educational projects in earth science were developed and are ongoing in a variety of situations and national contexts with the aim to disseminate meaningful information about earthquake risk and actions, which can be undertaken to reduce or mitigate its effects.
– The seismology may represent an efficient communication vehicle for teaching a wide range of basic science topics through experimental practices and educational activities.
– The seismology is an effective tool to raise in young citizens the awareness about the earthquake risk and possible mitigation actions.

Innovations and Findings

– Innovative teaching approaches based on web and net communication tools are well adapted to communicate and inform about natural hazards.
– The collaboration between researchers and teachers on the development of teaching tools on seismology is an innovative aspect in educational context and demands for a continuous and mutual effort to immerse oneself in the

(continued)

(continued)

shoes of the other, sharing the different languages, scientific backgrounds, levels and tools of the scientific communication.

- We find that the proposed approach stimulates the involvement of students having an active role in the knowledge process by observing, experimenting and measuring the natural phenomena using web-oriented and accessible data analysis tools, which provide a direct access to the seismological laboratory practice.

Implications for Wider Practice

- The installation inside the school of the seismic stations, specifically designed and realised for educational purposes, and the use of web-oriented and accessible data analysis tools have introduced the students to the seismological laboratory practice.
- A good implication for wider practice could be the experimentation of the e-learning model built upon earthquake science and educational materials and based on the Computer Supported Collaborative Learning (CSCL), an innovative method for teaching and learning which adopts modern information and communication technologies.
- Goals include the development of a new generation of educational geoscience websites making them as e-platforms for science communication and multimedia data sharing, where researchers, teachers, students and education operators can interact and constantly be kept informed of ongoing activities and relevant events.

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