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25 years of seismology at school in France

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Abstract (257 words)

An educational program focusing on seismological activities for student training in observational sciences and on raising citizen awareness of natural hazards has been active in France since 1995. Over this quarter century, different generations of students have learnt various lessons concerning instrument installation, data recording and analysis. These actions have led them into the field of scientific interrogation and interpretation, making them better prepared for our modern technological societies. We describe these student commitments motivated by the installation of the first educational broadband seismometer in southern France. Analysis of regional earthquakes has generated a strong awareness of the seismic hazard where students live, while records of strong earthquakes all around the world have induced interaction between students, especially after the deployment of additional seismometers at schools. The natural extension of such an educational seismic network, first at the national level in France in 2006 and later in many countries through various collaborations, has enriched the pedagogical practices of teachers, increasing their skills in seismology and natural sciences among various other disciplines complementing standard educational resources. We describe the necessary and sustainable relations between teachers and researchers over time. Combining students' motivation, teachers' experience and researchers' expertise has led to different hosting

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structures over the years. We conclude by presenting the feedback from a survey carried out in 2019 among all the teachers involved, highlighting the strong and weak points of such a long-term adventure. Recent integration into the official syllabus of the new Geosciences high-school curricula in France illustrates the impact of such an exceptional experience.

Introduction

Earthquakes occur suddenly and cause terrible damage to the infrastructures of our modern societies, leading to high numbers of casualties. These events are unavoidable but their impact can be significantly mitigated. They remain unpredictable with our current scientific knowledge. Moreover, they provoke trouble and fascination in our minds.
This is why emphasis must be placed on awareness, especially in the school system where the causes and effects of these hazards are studied. The idea of an educational seismic network arose in the United States with the Princeton Earth Physics Project proposed by Pr. G. Nolet and Pr. B. Phinney in 1993 (PEPP, Steinberg et al., 2000). Pursuing the same objective, an educational seismic network was initiated in France in 1995 and is still active after twenty-five years.
Today, many other educational seismic networks exist around the world, including the United States, Great Britain, Greece, Portugal, Australia, Nepal, Taiwan, Haiti and so on (Liang et al., 2016), providing an indication of the importance and need of distributing seismic sensors to schools for educational purposes. The installation of seismometers at schools promotes learning based on original records. Such learning makes students familiar with scientific data. With acquired experience, students can download other data from environmental agencies for their own investigation. It also provides the collaboration between teachers and researchers to better collect and analyze the seismic data. Such interaction allows teachers to develop teaching material in class. Moreover, this teaching material is provided on a website to other educators within the same discipline. It has been observed that these online resources have been used by a broader community of teachers in many fields, including natural sciences, history, geography, social sciences and so on.
Through this unique, long-term experience, this paper contributes to answering the following questions. How and why has the French educational system evolved over time and benefited from the deployment of a dedicated seismic network? Why is collecting scientific data inside a school important for both teachers and students? How have motivated teachers been able to elaborate online educational exercises to study their own data as well as the data that has become increasingly available on the web? How have such original educational resources been shared with other teachers across school and national boundaries? What skills and supports are needed to maintain an active educational network? Why can we not rely only on the open datasets available on the web? How has such an experience impacted French teaching programs?

"Sismo des écoles": the first French school network

In 1995, thanks to the PEPP initiative, the design of a dedicated educational seismometer began in France: a broadband 3-component velocimeter associated with a 24-bit high-dynamic digitizer synchronized by GPS with a precision of 1 msec (Fig. 1a). It was installed at the International Campus of Valbonne (CIV, pilot school). This sensor and its control card were monitored via a personal computer and a telephone line. In order to share scientific information between schools, the automatic nightly gathering of time-windowed records of local, regional, and long-distance events, when strong enough, was elaborated from the earthquake catalogs of international agencies. At that time, seismic sensors and related seismograms were more or less an abstraction for the school community. The first active group of 12 high school students was created, meeting weekly to share the analyses of seismograms from the station and related information collected through newspapers. This very committed group was supervised by a teacher in close interaction with a researcher, both involved in this prototype project at the CIV. For the very first time, students had immediate access to global earthquake seismicity from the seismometer within their school. The seismometer and its records provided some concrete aspects to virtual questions related to seismic hazard and to the knowledge of the Earth's structure, which are key scientific topics for French high school educational programs. Students and teachers tracked seismic events, such as the Chi Chi earthquake (Fig. 1b), as well as other natural or anthropogenic vibrations (swell, human activity, quarry blasts, etc.).

In 1996, the French Ministry of Education decided to connect all the schools to the Internet for student training. However, these institutions were very concerned about the added pedagogical value of the Internet in schools. The seismic network thus benefited from this evolution in connectivity: the prototype seismometer was connected to the Internet network. The first online educational seismic database was born. Teachers in other schools were able to work on the online seismic datasets. At the same time, regional political concerns focused on the education of young people about natural hazard awareness in one of the most active seismic zones in France. The prototype station demonstrated that an in-school seismic network to promote educational programs was possible: a first local financial contribution of the "Alpes Maritimes" region was granted. A network of five schools equipped with three-component broadband sensors was set up in the south of France (regional deployment in Fig. 1c, Virieux et al., 2000) and proved to be so successful that the extension to a national configuration was envisioned. The organization of such a network was based on voluntary proposals from a team of teachers. The equipment was provided free of charge while maintenance was the responsibility of the volunteer school.

An increasing network of teachers specialized in seismology

This network, which is constantly increasing, has been supported by different regional and national funds. In 2006, the French national "Sciences à l'École" organization integrated the existing "Sismo des écoles" network into their national educational projects. This cooperation enabled the transformation of local actions into widespread initiatives. The network, renamed "SISMOS à l'École", was first deployed on a national level, followed by international deployment in the French schools abroad illustrated in Figure 1c. This figure shows the part of professional and educational sensors. See "Data and Resources" for more details. In order to fulfill the educational target of seismic hazard education and scientific approaches, having teachers who are well-trained in seismological skills as an interface between teachers and researchers is mandatory and requires specific workshops. Each school with an installed sensor has an identified researcher (one teacher - one researcher as a mentor). Researchers have comprehensive knowledge of seismic phenomena and teachers have the pedagogical skills to describe these phenomena to students. Researchers have also contributed to the numerous training sessions through scientific refresher lectures. Furthermore, the researchers also use the network's datasets to integrate them into the seismicity study of the considered areas (Berenguer et al., 2013; their figure 6).

Regional, national, and international teachers' workshops

In the last 25 years, different meetings have been proposed to any teacher who wants to increase their own skills in seismological topics. In order to maintain significant momentum within the national (and overseas) network, six national meetings have been held since the beginning of the project, with a total of 200 teachers attending at least one of the proposed meetings. These ongoing training sessions thus keep the educational network alive. Topics are related to following items:

- scientific conferences presented by scientists and specialized teachers,
- practical workshops around datasets from the network,
- poster presentations to share experiences at different schools.

This format was finally recognized as very useful and helpful for the optimal use of scientific datasets, through the interaction of researchers participating in these teachers' workshops and with the participation of the young students whose awareness has been raised. At a different scale, European teachers' workshops were organized under the umbrella of European research projects, such as the NERA, O3E, and SERA projects (see "Acknowledgements"). These workshops, supported financially by these European projects, have provided the opportunity to

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mix the different cultural styles of educational training one can find among the different European countries.

A long-standing production of teaching resources

At the early stage of the network, the teachers shared their pedagogical experiences of exploiting in-school seismometers and available datasets on the web. Initial activities focused on the interpretation of dates, travel times and picks of seismic waves. With the accumulation of new data combined with their increasing seismological skill, teachers started to produce better-developed activities focusing on different and more complex aspects. The development of digital tools at school has enabled the development of original activities to manipulate numerical quantities. For example, by combining information from seismic catalogs and spreadsheet tools, students are able to display coordinates of listed seismic events on a map and observe that the distribution of each plot enables them to highlight areas which look like tectonic plates. Manipulating these catalogs by themselves enhances their understanding of where and how the information is obtained, which is an added value with respect to push-button applications. An extensive collection of different shared activities was undertaken and finalized through an exercise book: "Le cahier d'activités du SISMO" (the seismo hands-on book, Berenguer et al., 2009, Fig. 2a, see "Data and Resources"). This collection is an illustration of what can be done with the help of seismic data collected in schools. Quite sophisticated scientific topics may be tackled in a simple and pragmatic way during teaching and training. We can cite an example of a practical activity that has become very popular in the classroom. The experiment consists in causing the rupture of a rigid material (polystyrene, uncooked lasagna sheets, hard chocolate, etc.), and recording, with the help of simple piezoelectric cells, the waves that propagate around the rupture (Le cahier d'activités du SISMOS, pp.24-25). More activities are available in the digital version available on line (see "Data and Resources").

Successive web platforms to improve sharing

All records and activities have also centralized on successive dedicated web platforms for open sharing. At the origin of the project, a web server was hosted by the regional services of the French Ministry of Education. Thus, the records from regional and global seismic activity feed an online database and constitute a seismic resource center for education. Teaching requires a didactic approach to resources. The need for a more sophisticated platform emerged: this is why the web interface of our educational program goes beyond a simple data center. In 2010, the

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"www.edusismo.org" website was developed through funds provided by the French ministerial "Sciences à l'École" program. This website was a cornerstone to provide tools (experiments, software, and simulation) to properly exploit the available datasets as well as many different educational paths. The two first main digital tools used were:

- SeisGram2K (Lomax A., 2000, see "Data and Resources") software, an interface for the seismological research community and adapted for schools. Students can display seismograms, apply filtering processes, pick arrival times, and more;
- EduCarte geographical information software (see "Data and Resources") which enables users to plot geo-referenced information, work with seismograms, display GPS measurements, create cross sections, and more.

Making these datasets didactic through simple and well-developed working steps remains the priority of our program.

New impetus for natural risk prevention with the EduMed Observatory

Since 2017, University Côte d'Azur has taken over with the program called Educational Mediterranean Observatory ("EduMed-Obs", http://edumed.unice.fr). EduMed-Obs focuses on implementing an interface based on a geoscience dataset concerning the Mediterranean basin. The theme not only focuses on seismology: landslides, meteorology, hydrology, and sea-level variations are also considered. Data mining is developing and become preponderant in current teaching programs (Bigot-Cormier et al., 2017). These datasets are intended not only for middle and high schools, but also for university students. EduMed-Obs also provides datasets from research centers. This aspect is important to strengthen the visibility of the activities of research institutes. It is an excellent opportunity for students to compare datasets from their own sensors with research datasets. Making populations aware, through student training, of the role of earth science observatories is crucial and promotes a better understanding of the seismological (and environmental) nature of the territory where students live. How these observatories participate in our seismic risk awareness is better understood by political structures, inducing improved territorial management, such as tsunami mitigation. This new educational observatory already numbers some seventy European schools in the countries around the Mediterranean that host sensors and which implement scientific teaching focused on natural risk education (schools map available at http://edumed.unice.fr/fr/le-reseau-edumed). The schools that are twinned within this network can share their experience on natural risks along the Mediterranean coast. EduMed-Obs is a partner of many innovative field camp training courses organized around the

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Mediterranean, like "InsegnaciEtna 2019" in Sicily (http://site.ietna.eu). This expertise is already being exported through initiatives in Central America, where a network is being built on the Caribbean arc from Haiti to Venezuela via the French West Indies (http://edumed.unice.fr/fr/eduseis). The recent creation of EduMed-Obs as well as its present and future actions are directly inspired by the feedback from the teachers involved in this project over the past 25 years. Below, we propose a description of the key points mentioned by the teachers over the years.

A look at the past actions of the French educational seismological network

Teachers have reported a number of positive points from their experience: students' enthusiasm for recording quakes, the ease of understanding online databases, the development of autonomy, students' responsibility in managing a seismological station, the importance of natural risk within the theme of sustainable development. One of the great strengths of the network has been its integration into teaching programs, and to fulfill various expected educational objectives:

- practice a scientific approach;
- demonstrate observation skills, curiosity, critical thinking;
- experience autonomy;
- communicate in scientifically appropriate language: oral, written, graphical, numerical.

The installation of seismometers in schools in different areas of Europe and abroad has given the necessary impulse to use a scientific approach for the improved development of activities concerning the knowledge of hazard, the real-time manipulation of information and scientific databases, as well as a better understanding of matters related to risk and territorial management (Courboulex et al., 2012). However, it remains important to evaluate how this program has spread scientific culture and risk education to generations of students.

The "25 years of the French seismology at school" survey

After 25 years, the time had come to make an overview of the teachers' vision of the impact of this network on their teaching and on student training. A survey was conducted in November 2019 among all teachers who have participated in the various actions of the program since its beginning. Note that these teachers are all teachers who are, or who were, the school reference person for the seismometer installed in one of the 105 schools of the network. Several of them

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are (or were) in charge of teacher training sessions in France and abroad. The number of responses may seem small, but their answers reflect the feeling of many more people. Collecting all feelings, reflections and suggestions accumulated within the different special events carried out by the network should provide critical information for the future evolution of the educational network. Questions (Data Sheet S1) were listed in order to really quantify the impact of the program on their teaching and on the awareness of science culture and risk education among students. The results presented in Figure 2 are based on the responses of the 73% of the teams to have sent feedback, i.e a total of 250 teachers. In France, Earth science is traditionally taught by biology and geology teachers. They provided the major contribution (85% of the answers) to the survey (compared with the contribution of only 15% of physics teachers). Half of them are teachers who have participated in an educational seismology program for more than 6 years. They consist in equal numbers of middle- and high-school teachers. 80% of them (200 teachers) have participated in at least one of the training seminars on seismology and seismic risk described above. The main objective of the survey concerns the pedagogical value of installing a seismometer in a school. What is the greatest contribution of such instrument in a classroom? The following interests are listed in descending order. The program has proven to be a facilitator for:

- practical support for science education (75.3%)
- seismic risk awareness (70.1%)
- creation of a science club (68.8%)
- discovery of the world of research (66.3%)
- exchanges within a network of schools and researchers (65.6%)
- practical support for technology (58.5%)
- stimulating the interest of parents (45.5%)

The survey confirms that a seismometer installed in schools is an essential educational element for the majority of teachers. From teacher feedback, we also note that, through this sensor installed at the school, most of the students have acquired skills to become ambassadors for seismic risk. Indeed, teachers mentioned that many students were invited to participate in scientific events in order to present their work. It can be considered that at least 20,000 students have been able to participate in and benefit from the educational seismology program in France. Many of them are adults today, some of them have chosen a scientific career, but all are citizens who have been made aware of seismic risk by studying seismic phenomenon through the analysis of seismic data provided by educational and research seismometers.

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CONCLUSION

All teachers agree on the fact that the presence of a seismometer at school is of great interest to fulfill the main objectives of scientific culture and seismic risk education. Many other seismological networks for educational purposes have also emerged in Europe and around the world. Such educational programs have shown a positive impact among students (Zollo et al., 2014). Educational seismological networks also draw their strength from the interaction between teachers and researchers which has occurred under various circumstances. If citizen science and educational seismology occupy such a prominent place in society today, it is because they ask for citizen commitment on important issues, such as the prevention of seismic risk and, more generally, of natural risks. Schools play a central role when addressing a young public. The place of scientific research is also essential for better mitigation of natural hazards and to better understand the anthropogenic impact on environmental systems. Therefore, through this long-standing educational program with the driving motivation of building a seismic network across different educational communities in Europe, we must definitely focus on prevention through education. Educational seismology networks do more because they encourage students to adopt a scientific approach based on observation and measurement, enabling them to understand the causes of earthquakes, the internal dynamics of the globe... and to learn how to behave.

Finally, the challenge of educational seismology is the improved training of our students in Earth science so that they have a better understanding of how science is constructed and how it progresses. Undoubtedly, trained citizens are better equipped to face their future with a strengthened science-citizen link, and scientific vocations are the rewards of such innovative and attractive training.

Data and Resources

The book "Le Cahier d'activités du SISMO, version 2", funded by the Alcotra Program (European Union), was developed in 2009 and published by the School District of Nice (France). A digital version is available at the following URL:

- http://namazu.unice.fr/EDUMEDOBS/seismo/seismobook-version2.zip

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SeisGram2K and EduCarte (developed by Anthony Lomax and Jean-Luc Berenguer) software is downloadable at the following URLs:

- http://edumed.unice.fr/fr/contents/news/tools-lab/SeisGram2K
- http://edumed.unice.fr/fr/contents/news/tools-lab/EduCarte

The professional seismometers deployed during the initial, regional and national phases were the S.A.G.E station with a 3-component velocimeter (Noemax 20s). During the national phase, Güralp CMG 6TD were also deployed, such as the educational Vibrato station (https://www.staneo.fr/vibrato.php). This device and the TC1 seismometer (Van Wijk et. Al, 2013) are currently deployed (EduMed-Obs phase).

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Figure captions

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Figure 1: First educational seismic stations deployed at the Valbonne International School. (a) Students working on seismograms from a specific educational database. Informed consent was provided by the individuals pictured for the publication of these identifiable images. (b) Record of the Chi Chi earthquake (Taiwan, Mw 7.6), which occurred on September 20, 1999 and was recorded at the French educational CIVF seismic station. Values in abscissa are hours of the current day (UTC time, p.m.). (c) Evolution of the number of educational seismometers deployed during the past equipping phase of the French educational network, and currently with the EduMed-Obs project. Colors under the curve and corresponding colored boxes give an indication of the kind of sensors deployed during each phase. See "Data and Resources" for further details.

Figure 2: Focus on teachers' answers to the survey. In this case, the graph shows the impact of the installation of a seismometer in a school, relative to different considerations.

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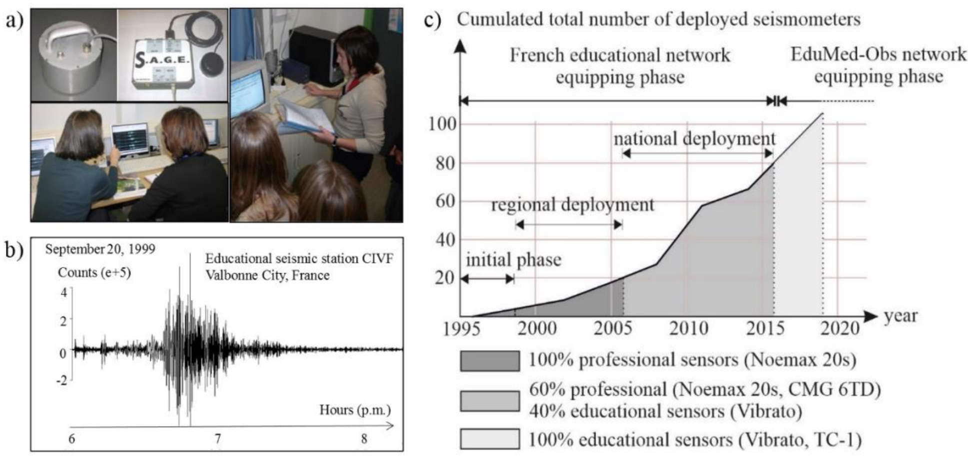
Figures



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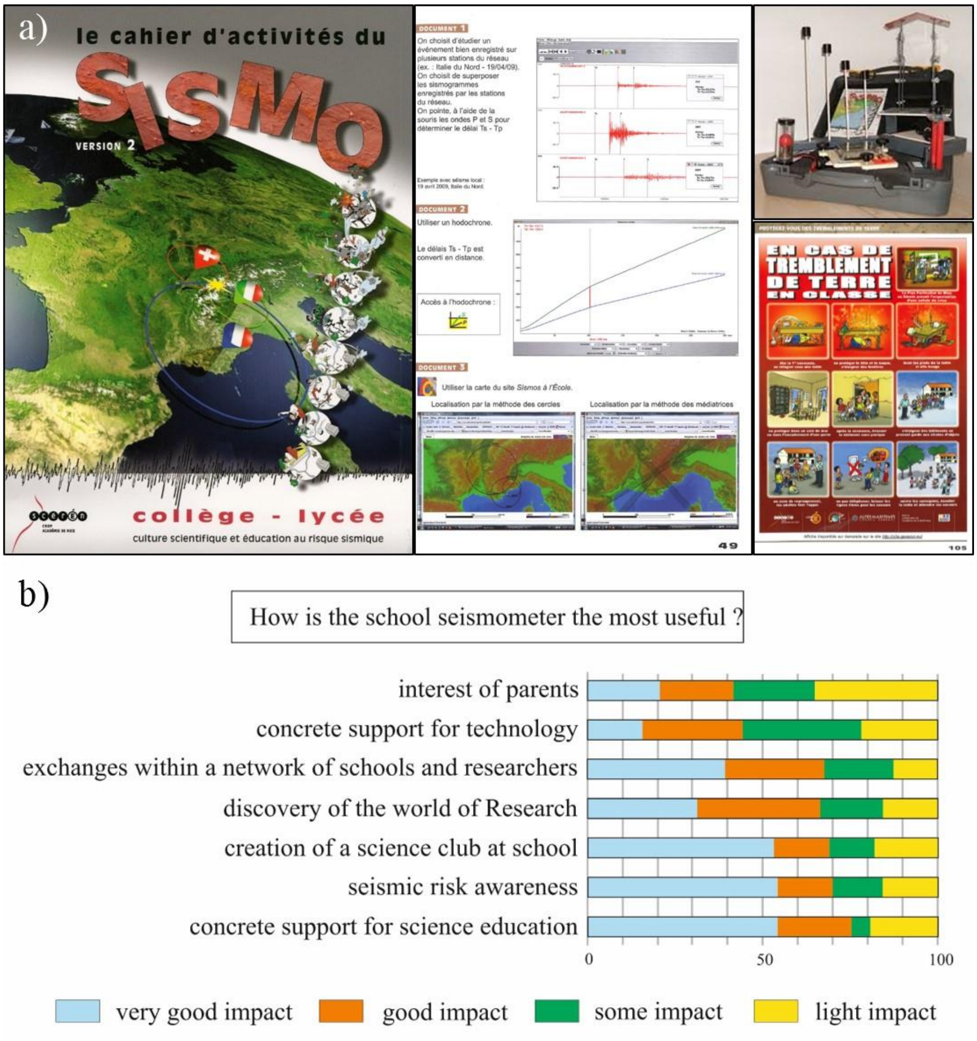

Figure 2: Pedagogical resources produced by the French educational network. (a) The “seismo” exercise book and the “seismo” box used to illustrate many aspects of the seismic phenomenon. (b) Focus on teachers’ answers to the survey. In this case, the graph shows the impact of the installation of a seismometer in a school, relative to different considerations.