Report on Discussion Workshop for Educational and Citizen Seismology

Held at the Geological Society Meeting Rooms in London on 15-16 Feb 2018
by
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Most of what we know about Earth's structure, dynamics, hazards, resources and exploration for raw materials comes from seismology but it is only recently, thanks to the availability of cheap computers and the internet, that it has become possible to introduce the subject in schools and include live displays in museums and Geoparks for the general public. For these purposes high quality sealed observatory-type units are not ideal and a variety of small simple comprehensible low cost seismometers and software have been developing across the globe. They range from laboratory sized replicas of the Milne-Shaw type (Figs 1 and 2), through ones using slinkies (Fig 3) and lego building blocks to smart phones which are used for detection and communication. Data from these varied devices are pooled and stored at data centres to facilitate data exchange and discussion. As the educational value of the subject is becoming more widely appreciated the need for an international discussion workshop for Educational and Citizen Seismology became apparent. This was held at the Geological Society meeting rooms in London 15-16 February 2018, with financial support from The British Geophysical Association, UNESCO and the EU.. At the meeting it was noted that MarsQuake project data from NASA's InSight mission to Mars launched on May 5 2018 will provide a set of teaching resources and activities.

The meeting was designed as a forum for experts in educational and citizen seismology to get together and discuss areas of mutual interest and discover potential synergies and future collaborations. The meeting was scheduled with a balance between keynote talks and discussion or demonstration sessions. The format was to have some keynote addresses from the most experienced experts in developing equipment and running school and citizen seismology programmes to facilitate future collaboration and encourage the growing number of institutions round the globe interested in developing such programmes. There were breakout discussion groups on motivating leaders and maintaining engagement, hardware and software development, data sharing standards and archiving.

In the USA school seismology emerged from the IRIS (Incorporated Research Institutions for Seismology) consortium funded by the National Science Foundation since 1992 to meet the demands of Scientists in Universities and research institutions for large numbers of instruments, operators and software in a wide variety of projects. In the UK this process has been overseen and supported by the British Geological Survey under the direction of Paul Denton who developed the interest while he was at the University of Leicester where the national pool of seismic equipment is housed and maintained. In 2017 a new EU Horizon 2020 funded project SERA (**S**eismology and **E**arthquake Engineering

Research Infrastructure **A**lliance for Europe) was approved and included support for school seismology groups from UK, France, Switzerland, Romania, Portugal and Greece to work closely together, with specific interests in developing collaborations and finding synergies with the growing citizen science movement involved in seismology. This is typified by the Raspberry Shake project, which arose from a successful Kickstarter campaign in 2016 by seismologists in Panama and already has over 600 participants across the world (Fig 4), all recording and sharing seismic data on inexpensive raspberry pi/geophone based sensors (www.raspberryshake.org). Within Europe the European-Mediterranean Seismological Centre (EMSC) has led the way in citizen seismology with smartphone and web based citizen seismology activities. The worldwide educational potential of the activity is indicated by the support provided by the UNESCO.

The meeting was attended by 47 registered delegates from 16 different countries (Australia, France, Greece, Ireland, Israel, Italy, Nepal, New Zealand, Palestine, Panama, Portugal, Romania, Spain, Sweden, Switzerland, Trinidad, UK, and the USA) who have been doing school seismology in a variety of different ways, some for decades and some just starting. Groups everywhere usually included seismologists from a local university or regional network working with teachers and officers from national educational bodies. We are also seeing the emergence of amateur seismologists as the costs of simple instruments and computers including smart phones are now affordable. There were senior participants who retired from the seismic instrument industry and are applying their expertise to making affordable versions of sophisticated observatory instruments for school and amateur use.

Each group has a slightly different motivation for setting up their projects. In countries with high seismicity a strong motivation was education of the population about seismic hazard and risk. In the case of citizen projects this also spreads into a motivation to move towards integration with earthquake early warning systems. In countries with low seismicity the educational motivation is more towards a desire to stimulate interest in geoscience at school level and hence build capacity in geosciences at graduate level. More broadly, the earth has been used as a stimulating laboratory for introducing many physics concepts including gravity, magnetism, electricity, and radioactivity. But it is only recently has it been possible to include the many physical concepts embraced by the propagation, detection and analysis of seismic waves which have had complex paths through the earth. School seismology therefore has a role to play in stimulating more students to study physics and mathematics at school.

The first keynote address was by Remy Bossu, the Secretary General, European-Mediterranean Seismological Centre (EMSC) on **Why is LastQuake a successful citizen Science project**. LastQuake is an app which people launch when they feel an earthquake. The location of the phone launching the app is immediately plotted on a map at a data centre(Fig 4). Eyewitnesses act as seismic sensors: they feel the ground shaking and by launching the app (or visiting our websites) report the time and location of their observation. The response is very fast and as more launches occur a dotted area emerges and outlines the

affected area and provides a lot of useful information about the origin of the earthquake as in Fig 5
Messages can be sent to the people with the app saying where the earthquake is and this in turn generates more responses as they launch. The response pattern is complicated by the magnitudes. For large earthquakes there is a ‘doughnut effect’ i.e. a blank zone near the epicentre where people know there is an earthquake and don’t need to launch the app to find out where it is. They may call for advice which is readily provided. Magnitudes can be estimated qualitatively as being small, medium, or large. It was an exciting demonstration of how useful Apps can be in contributing to risk reduction.

The second Keynote talk was one of the meeting highlights presented by Angel Rodrigues of Panama on **the past, present and future of the Raspberry Shake**, (Fig 6) a sensor digitiser that can record earthquakes from about magnitude 2 and higher within a radius of 50 miles, and a magnitude 4 and higher in a radius of 300 miles. It will also record earthquakes of larger magnitudes farther away but with some loss of information. Raspberry Shake can detect and record short period (0.5 - 15 Hz) earthquakes but the range of recordable frequencies falls off with distance. The hardware can hardly be cheaper. However the software is costly but comprehensive and easy to use. In just 14 months over 500 stations have been installed, 133 of these in Europe. It is cheap and fun to use for vibrations ranging from washing machines, goals at football matches and pop-concerts to small earth tremors from earthquakes and volcanoes. It is affordable by amateurs and has obvious application in citizen and school seismology. They can be deployed in large numbers and detect earthquakes too small to be detected by Regional Networks.

The presentation by Richard Allen, Director, Berkeley Seismology Lab on **Earthquake alerts from crowdsource sensing** was on a similar theme. It uses the myriad of data from the accelerometers in smartphones to create alerts by its remarkable ability to distinguish earthquake signals from the much larger ones resulting from the noise due the motion of the smartphone carried by the user. A network detection algorithm MyShake can confirm that an earthquake is underway and estimate the location and magnitude in real time. This information can then be used to issue an alert of forthcoming ground shaking. could be used to enhance EEW in regions with traditional networks and could provide the only EEW capability in regions without. In addition, the seismic waveforms recorded could be used to deliver rapid microseism maps, study impacts etc. In the US alerts were generated for earthquakes of magnitudes down to 1.6. The potential was demonstrated by an earthquake in Nepal where there are few conventional seismic stations but several million smartphones.

John Taber, the Director of Education and Public Outreach in IRIS gave the third Keynote presentation on the comprehensive **Educational Seismology programme in the USA**. Its activities ranged from formal educational and professional development to less formal activities on the web, and displays using social media for the general public. The programmes started from Princeton in 1992 with 80 schools using low cost versions of the Guralp feedback seismometer which is widely used in observatories. The AMASEIS software was developed to permit real time streaming of data to a data centre for use in locating and studying earthquakes. Schools anywhere in the world can register to download and upload data from and to the system. The educational value of being able to do this is enormous. Over the years regional networks have developed in the US with tens of schools whose teachers work with seismologists in the classroom. In Indiana there is an annual student research symposium. The school students value spending a day at the campus and presenting their data. Teachers value linking with universities which in turn benefit from making contact with high quality students. There is ongoing collaboration with the UK and Ireland. Over 150 US schools and 200 international schools use the IRIS facility. There is a plan to expand it to include the data from Mars. Problems encountered in the US and elsewhere include overcoming firewalls in schools, and the lack of teacher continuity which can interrupt teachers helping each other.

A different kind of school project, **AUSIS the Australian School Seismic Network** was described in the 4th Keynote talk by Michelle Salmon from the ANU. It is a partnership between research and outreach. Research quality Guralp seismometers are installed and connected to school computers in schools and used to increase the density of the country's sparse network. So far 47 schools have such instruments. There are some problems due to fact that the hardware and software are not ideal for schools which are sometimes too remote for interaction with seismologists. A lot of useful contacts and suggestions were made to improve the working of the partnership.

The school programme in New Zealand was rather different. A talk on RU: The New Zealand Network for Seismology in Schools was presented via Video link by Kasper van Wijk, Associate Professor, University of Auckland. There is a strong cultural link with the earth as complicated belts of high seismic and volcanic activity define plate boundaries which go through New Zealand. There is a history of large earthquakes and there a national network Geonet whose data as well as those from the USGS are accessible. The school seismometers were based on slinkies with magnets at the end and connected to a raspberry pi running Jamaseis software. The students were involved in assembling 17 school seismometers from kits which were distributed throughout New Zealand with one on a small island to the east. They can download data, plot record sections, identify P and S waves, and draw circles to produce seismicity maps. One interesting refinement is the addition of notch filters to remove ocean noise as was fashionable in observatories nearly a century ago. It is a highly effective programme but is poorly funded and will be difficult to maintain. IT support is very small. As in other parts of the world, they are working towards getting seismology into the school Curriculum to increase and maintain teacher interest.

Jean-Luc Berenguer, Science Teacher & French seismo network Project leader gave the 5th keynote talk on **Tuned in to Mars… from 'SISMOS à l'Ecole' with SEIS InSight**. The French have been doing teaching seismology for over 20 years in French schools all over the world. Seismology is in the curriculum and there are Geoscience teachers able to teach the subject in geography, physics, and maths courses. There is a database for education. Seismometers may be of the blackbox or TC1 variety depending on the preference of the school. Special software like AMASEIS has been created for them. These are supplemented by laboratory models to simulate earth materials – lasagne and warm or cold chocolate from the fridge were mentioned. Non- computer literate students find these particularly useful. Schools are encouraged to communicate with each other and with the project HQ to exchange ideas and information. Schools have invited to apply for selection to work on data from the seismic data from the InSight space mission data from Mars. 15 schools accepted the challenge and will be selected on how they perform with a set of synthetic data they were sent to work on.

Susana Custodia of the University of Lisbon gave an illuminating talk on the interface between citizen science and civil protection in Portugal which has the largest earthquakes in Europe. Indeed the largest earthquake in Europe was the devastating 1755 offshore Lisbon Earthquake which occurred on All Saints Day and was regarded as another act of God. But it was the starting point of modern seismology as people began to enquire about the effects in the rest of Europe including the UK and Ireland. There was a magnitude 7.9 earthquake in 1969 so there is a high degree of awareness and the University is called upon to advise on seismology in schools and in the country at large. Interestingly the enquiries in schools come from biology teachers who seek help from physicists in building their own detectors and even shake tables to study the effects on buildings. One graduate student is using Ocean Bottom Seismometers to study the sounds of whales. The civil authorities are actively involved with making risk maps and developing civil protection measures.

Similar objectives relating earthquake damage were mentioned by participants from other seismic areas – Nicos Melis in Greece, Francesco Finazzi in Italy, Shiba Subedi and Surya Acharya from Nepal, Wist Bloch Israel. Rondell Liverpool is involved with a new school programme in Trinidad and Tobago where the Caribbean Seismic Network is based and needs to expand to the volcanic islands some of which already have French and American stations to link with.

Other citizen seismic issues mentioned during the meeting were the monitoring of fracking by Anna Horleston of Bristol and Jefferson Chang of Oklahoma, landslides by Emma Bee and the CTBT by Thomas Blake from the Dublin Institute for Advanced Studies.

A common problem which was mentioned in the discussions was that of maintaining the interest of secondary school teachers where the seismology was not in the curriculum. But occasionally the converse occurs with enthusiastic teachers who obtain spectacular results. A good example is Vika Moisey, a primary school teacher from the Birdwell Academy in Bristol who was able to get 9 year old pupils enthused about earthquake waves, damage, and convection in the earth. They even built their own detector. They entered and won the young scientists competition in 2014 and there is a paper in the young scientists journal Issue 17. It is a useful pointer for the future as there is a need to get younger people interested in physical science as early as possible to fill university places in science and engineering to address the issue of manpower shortages in these areas.

The meeting was the first international meeting of its kind and was welcomed as school and citizen seismology was an important fast moving subject being developed with limited resources in most cases. The doors are open for a continuing exchange of ideas and future collaboration. The activities benefit from the outreach element from the existing Regional Networks of sparsely distributed sophisticated instruments. There are huge additional potential benefits to be gained from the large numbers of simple instruments acquiring data.

The initiation by the SERA group and support from UNESCO are good pointers for the future. There is a long way to go and the need for regular meetings was emphasised. It was agreed that the coordination would continue with planned shared sessions at the ESC meeting in Malta in September 2018 and the 2019 joint assembly of IASPEI and IUGG in Montreal.

All of the presentations at the meeting have been videoed and are available to view at http://www.bgs.ac.uk/discoveringGeology/hazards/earthquakes/schoolSeismology/seismoATschool/EduCitiSeis2018.html

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Fig Captions

1. John Milne with Japanese wife and Russian Colleague and his room-sized seismograph

2. Miniature SEP Milne seismograph replica for school and amateur use. Base length about 50cm.

3. Slinky seismograph with a Raspberry Shake

4 Density by region of the 13.9 million LastQuake app launches from May 2015 to end of December 2017. Users are present at different levels in all seismically-active regions of the globe (except China where access to Google and Apple stores is not granted)

5. Each dot represents a unique app being launched within 180 s of the M 5.6 earthquake (star), at 91 km of depth, in Romania on December 27, 2016. The colour of the dots illustrates the time lapse from the occurrence of the earthquake. The first launch happened 36 s after the earthquake, knowing that the P-wave (the first seismic waves) reached the ground surface in 12.7 s and the S-wave (the more energetic wave) did so in 22.2 s. There were 931 launches within 180 s of the earthquake. The circles represent the front of the P and S seismic waves 60 s after the earthquake.

6 A Raspberry Shake

7. Raspberry Pi distribution map after 14 months

8 Allen Noise and earthquakes on smartphones
9 Allen Record section
10 Allen smartphone and observatory records compared

11 Participants examining each other's seismometers

12 Participants at evening discussion

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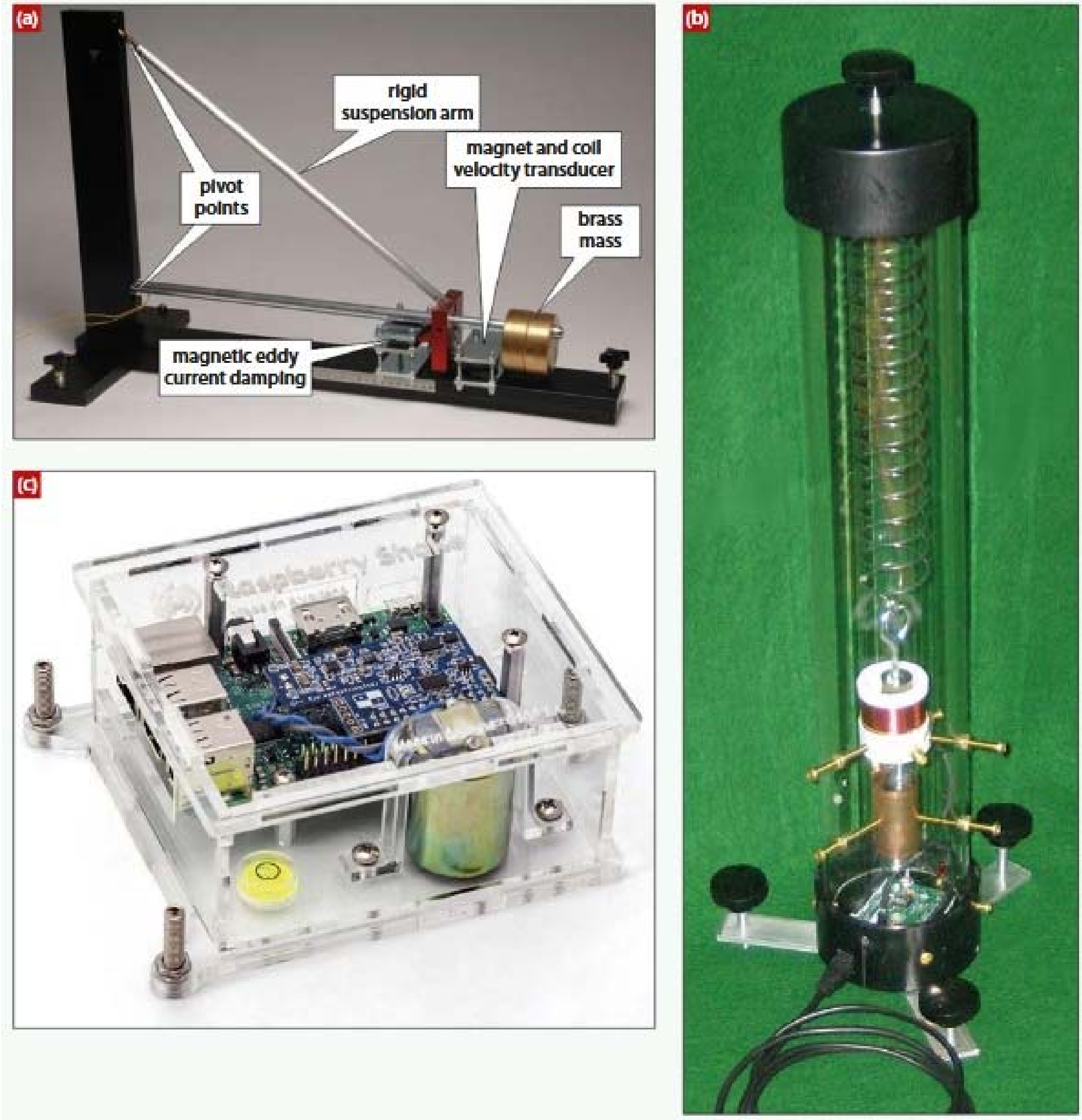
(a)
rigid suspension arm
magnet and coil velocity transducer
pivot points
brass mass
magnetic eddy current damping
(b)
(c)