Cultivating Citizen Scientists with Seismic Monitoring in Texas and New England Using an Affordable Seismograph

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Summary

Texas Educational Seismic Project (TXESP), together with the Boston College Educational Seismology Project (BCESP), share a mission to take real world events and turn them into "Teachable Moments". In pursuit of our mission, both TXESP and BCESP use seismology as an exciting medium for inviting students into the world of scientific monitoring; we are highly motivated to promote inquiry-based learning through investigation of earthquakes recorded by seismographs in classrooms. It is truly fascinating that it is possible to record earthquakes that occur across Texas and New England using a new, simple seismograph – the Raspberry Shake seismograph. Seismographs record many types of ground motions: earthquakes, volcanic eruptions, human-made explosions, and even local traffic! Historically, real-time earthquake monitoring and analysis required very large, high cost, and professional laboratory quality instruments. However, very recently the Raspberry Shake seismograph revolutionized citizen science capabilities. The question we ask is "Can the Raspberry Shake seismograph provide high quality data similar to other educational and laboratory seismographs?" Raspberry Shake offers a simple "plug-and-play" affordable seismograph which offers great flexibility for users. Affordability and flexibility expands opportunities for low to median income (LMI) students – giving them research experiences investigating what is recorded on their classroom seismograph and promoting a valuable positive step in the direction of inquiry-based science education and college readiness.

Cultivating Citizen Scientists

Texas Educational Seismic Project's "Cultivating Citizen Scientists" program is fundamentally a student-led seismic monitoring and research project which furthers familiarity with scientific and engineering analyses, the concept of uncertainty, and interpersonal communication – skill sets which are vital for college readiness. TXESP chooses to bring its program to Texas Educational Agency's state-designated disadvantaged campuses. The affordability of the Raspberry Shake enables TXESP to reach LMI schools and non-traditional learning centers (Christensen, 2016). Citizen scientists are heavily involved with innovative technology (seismographs and video-conferencing), and we believe that this particular element also facilitates a step-up for LMI populations who generally have little access to computers, laboratory instruments, and curriculum. The Raspberry Shake, its software, and our accomplished team of Scientists and Science Education experts increase these classrooms' progress in "real-world" seismic monitoring, and it demonstrates how science is actually practiced.

Overseen by our science-education and monitoring team, students in our "Citizen Scientists" program study, record, and interpret natural geologic phenomena through visual experiences and hands-on activities, explore and test student-led inquiries, and ultimately develop critical peer-to-peer communication skills. These accomplishments are made possible by TXESP and its collaboration partner, BCESP. BCESP is operated by Boston College's Weston Observatory (a research and seismic monitoring center of the BC Department of Earth and Environmental Sciences). To deliver on our mission's goal, we enhance science classroom education by offering opportunities for students and their teachers to be directly involved with a team of research scientists – in Texas and New England – as part of their "real-world" experiences. The science of seismology, particularly seismic monitoring, forms an excellent foundation for this endeavor because: (1) it is an inter-disciplinary science that requires understanding a broad range of STEM concepts, and (2) it teaches students how the natural environment and human-made events impact our daily lives. Thus, seismology offers numerous possibilities for introducing students to the nature of scientific inquiry and enhancing their connection to "real-world" activities.

Seismic Monitoring with Raspberry Shake Seismographs

Technology innovation and affordability advantages of the Raspberry Shake seismograph enables TXESP's program to obtain a wider reach within LMI communities; but, the question we ask is "Can the Raspberry Shake seismograph provide high quality data similar to other educational and laboratory seismographs?" We also are searching for technology solutions which enhance current pedagogy in the classrooms and increase knowledge uptake.

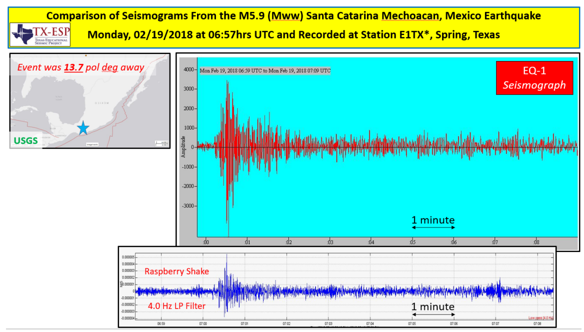
With one classroom Raspberry Shake seismograph, all students at a school may benefit from multiple, large monitors (computer screens) across a campus. Data captured by the Raspberry Shake is "pushed" to a primary repository where it may be accessed globally by internet users. Required viewing software is available for free online, and any user may begin "watching the ground move" immediately once the software is installed. This multi-user strategy also facilitates seismic monitoring, and analysis, between Texas and New England schools and other education entities. For example, New England students benefit by monitoring seismographs in Texas, which are closer to plate tectonic boundaries and record many more earthquakes, and by interpreting wave phase arrivals. Texas students benefit by comparing seismograms and recognizing the concept of wave propagation and attenuation over long distances.

Curriculum allows students to learn concepts, but recording an earthquake and then resolving a near real-time challenge (applying knowledge), is in our experience far more impactful. Example: attaining pedagogy success when teaching about plate tectonics after a moderate or large damaging earthquake occurs (magnitudes greater than Mb=5.0) during the school day. These "Teachable Moments" leverage the earthquake event as an opportunity to discuss Earth's naturally-occurring dynamic behavior, interpret supporting evidence, and brainstorm a line of student-led inquiry. Observing seismic events as they happen, interprting them, reading damage and loss reports, and discerning if the ground motion was natural or human-made, all aid to cement hard memories for students and make knowledge uptake impactful. In this example, student-led inquiries leap to open-ended discussions about geohazard prediction and environmental engineering mitigation. Local events give students a personal connection to analyses and associated uncertainties.

Comparing Technology

When we first approached this idea of "Cultivating Citizen Scientists", we wondered if the Raspberry Shake instrument would be able to detect and record local and global seismic events with similar data quality to existing educational seismographs, such as the AS1 an the EQ1, and possibly even to high quality laboratory seismographs. Both TXESP and BCESP have multiple seismographs at our main research locations. When a moderate or large earthquake was detected and recorded on the devices, we extracted seismograms on all instruments and compared the wave amplitude and character of the seismograms between the different seismographs.

First, a quick comparison was made by visual inspection using seismograms created by each instrument's "preferred" software program. We utilized jAmaSeis available for free from Incorporated Research Institutions for Seismology, or IRIS (2001), to view seismograms extracted from AS1 and EQ1 data; Raspberry Shake users download free viewing software called SWARM (Cervelli et al, 2004). Once seismograms were created for an event, we aligned the images side-by-side and on the same time scale. Visual confirmation determined if the detection capability of the Raspberry Shake was similar enough to the other seismographs and thus sufficient for classroom seismic monitoring, see Figures 1a and 1b.



**Interpretation and comparison completed by Texas Educational Seismic Project.*

Figure 1a: Shown is a comparison of seismograms from the February 19, 2018 Mexican earthquake.

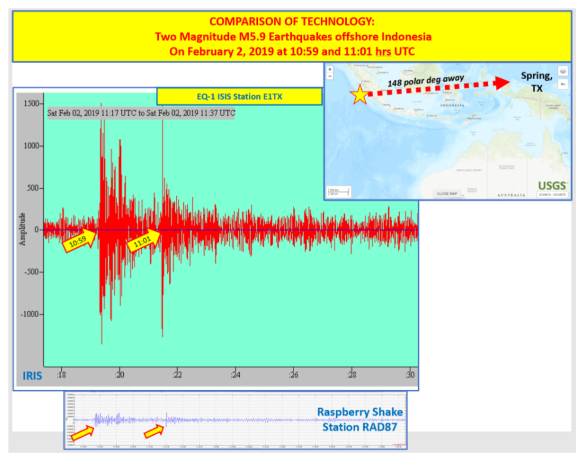


Figure 1b: Shown is a comparison of seismograms from the two February 19, 2018 Indonesian earthquakes.

Cultivating Citizen Scientists

After significant earthquakes, Weston Observatory compared seismograms recorded by expensive, research-quality seismographs with seismograms of the same earthquakes recorded by low-cost educational instruments. See Figure 2 (Fink et al, 2018).

Boston College Educational Seismology Project compares the amplitude and character of three seismograms interpreted from data on: a Broadband Research-Quality, an EQ1, and a Raspberry Shake seismograph.

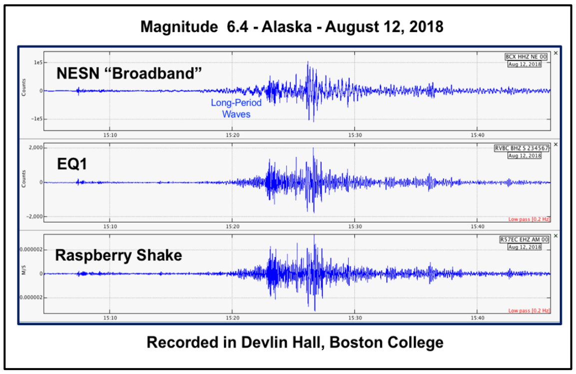


Figure 2: Shown is a comparison of seismograms from the large August 12, 2018 Alaskan earthquake.

Conclusions

TXESP and BCESP are delivering successful programs which are heavily dependent on affordable and quality science instruments. Our first question in STEM outreach, “Can the Raspberry Shake seismograph provide high quality data similar to other educational and laboratory seismographs?” can be answered confidently as “Yes.” Visual and detailed comparisons of Broadband, EQ1, AS1 seismograms, with Raspberry Shake seismograms, reveal that reasonable quality seismograms for conducting citizen scientific research and monitoring seismic activity is possible. Raspberry Shake seismographs offer students experiences previously not available due to budgetary constraints. Open-ended, inquiry-based discussions build students’ confidence, increase knowledge uptake and demonstrate how science is practiced in the real world. We anticipate that the expansion of seismic monitoring at more campuses will yield new citizen scientists who will develop deeper insights into natural and human-made seismic events.

Acknowledgments

The authors appreciate the financial support from private donors to TXESP and also from Weston Observatory, Department of Earth and Environmental Sciences, Boston College; the Boston College Educational Seismology Project team, specifically Anastasia Moulis and Marilyn Bibeau for their contributions in instrumentation deployment and monitoring; and we are grateful for the technical support provided by Raspberry Shake’s developer, Branden Christensen, and staff.