After the Lorca earthquake of 2011 there was a general recognition that, despite the sound seismic behaviour of civil buildings, there were important deficiencies in non-structural elements, as well as disinformation and errors in the behaviour of the authorities and the public at large. This earthquake was a classic example of the type of seismic episodes to be expected in Spain. Although these episodes cannot be predicted, their effects can be prevented. In fact material- and human-damage-mitigation measures are simple, cheap and efficient. Within the DimeRisk project, therefore, an analysis has been made of the Spanish population's awareness of and information on seismic risk and the main lessons to be learnt from the Lorca earthquake, with the aim of drawing up an educational and training plan to reduce seismic risk in Spain.


After the Lorca earthquake of 2011(1)(2)(3) there was a general recognition that, despite the sound seismic behaviour of civil structures (buildings, bridges, etc.; during the earthquake only one building actually collapsed), there were important deficiencies in non-structural elements (cornices, overhangs, enclosure and non-weight-bearing walls, false ceilings, etc. (figure 1), as well as disinformation and errors in the behaviour of the authorities and the public at large (inappropriate earthquake reaction, inefficient building evacuation drills, confused housing-damage classification codes, etc.). The buildings themselves and structural elements abided by a strict, collapse-avoiding earthquake-resistant construction standard (Norma de Construcción Sismorresistente Española, 2002)(4). Nonetheless, ignorance of basic damage- and victim prevention and -mitigation measures, such as fixing non-structural elements, self-protection measures and behaviour (figures 1 and 2), was the cause of most of the victims (9 deaths and 324 injuries) and a good deal of the material damage associated with the non-structural elements (the biggest loss event ever dealt with by the Consorcio de Compensación de Seguros [Insurance Clearing Consortium], which paid out 460 million euros).

Earthquakes are not predictable with today's technology, though we do know which areas are most likely to suffer them and the magnitudes that might be expected. Seismic movements cannot be predicted but the effects can be prevented. In Spain earthquakes of medium and moderate magnitude (magnitude of less than 6.5-7) have occurred in the past and could recur in the future.
structures, there were important deficiencies in non-structural elements as well as disinformation and errors in the behaviour of the authorities and the public at large. Especially in southeast Spain (5). Although the rest of the Iberian Peninsula has also suffered big quakes, such as the Lisbon earthquake and tsunami of 1755 (one of Europe’s most destructive events ever, with a death toll of 15,000 in Spain alone), there is a lack of awareness about the risks they pose. This dearth of social awareness and seismic-risk prevention planning in Spain is due to the fact that earthquake return periods are very long, i.e., the interval of time between earthquakes adds up to many years. Nonetheless, earthquakes of moderate magnitude but of great destructiveness have hit Spain on many occasions, such as those of Arenas del Rey in Granada (intensity IX-X), Torrevieja in Alicante (intensity IX-X), Lorca (intensity VI) and even the Lisbon earthquake that occurred off the coast of the Cabo de San Vicente (5). Although magnitudes were medium (albeit with some higher than 6) or moderate, the high population density and the existence of old parts of Spanish cities with no modern earthquake-resistant construction techniques mean that both personal and economic damage could be very high (2).

The Lorca earthquake of 2011 (magnitude 5.1) was an example of the type of seismic events that might be expected in southeast Spain, of moderate magnitude but affecting densely populated zones with old inner-city zones and a population with little seismic training or instruction (1)(2)(3) (figures 1 and 2). Despite their moderate magnitude, therefore, these quakes take a heavy toll in damage and human victims.

Figure 1. In the Lorca earthquake of 2011 it was the fall of non-structural elements like cornices, façade slabs or non-weight-bearing walls that caused most material damage and victims. This earthquake is an example of the damage that a Spanish city might suffer from a seismic event of moderate magnitude.

Figure 2. Following the Lorca earthquake of 2011 an identification was made of the most typically hazardous elements in a house. For example: a.- wardrobe doors not latched closed, b.- shelf items liable to fall on beds or sofas, and c.- heavy items likely to fall on persons and cause serious injury.

Measures to mitigate human and material damage might become very complex, but in earthquakes where construction withstand collapse, the self-protection and mitigation measures are simple, cheap and effective, and are widely implemented in many countries (e.g., United States, Italy, Mexico and New Zealand) (6)(7)(8). These countries run education and awareness-raising programmes in schools, homes and workplaces that considerably reduce earthquake damage and losses.

Earthquake knowledge is the first step towards citizen awareness and recognition of the self-protection measures to be applied whenever they occur. Recognising the hazardous of the zone of residence, knowing what an earthquake is and why they occur are fundamental aspects in understanding which prevention and self-protection measures could be adopted. These measures are simple and low-cost, such as identifying the hazardous elements to eliminate them or fasten them to prevent them from falling and breaking or injuring people (e.g. bolting shelves to the wall, fastening television sets and
The Lorca earthquake was an example of the type of earthquakes that might be expected in Spain, with moderate magnitudes but affecting densely populated areas (figure 2). Other measures that might be adopted during an earthquake are to take refuge under a table, keep calm and, above all, not to run out of the house. Emergency plans with clear evacuation routes should also be followed; gas taps should be shut, and lifts, telephones and switches should not be used.

After the Lorca earthquake, the members of the DimeRisk project, made up by primary- and secondary-school teachers and scientific teams specialising in the study of seismic episodes and also secondary-school teachers of Lorca and Seville with experience in the teaching of earth sciences, pinpointed the problems of disinformation, ignorance of earthquake hazards and the basic measures to be taken. The many websites with information, posters and lists of dos and don’ts did not seem to be efficient ways of raising awareness about this natural risk.

The Lorca earthquake, moreover, enabled an identification to be made of the main problems that might be found in an earthquake of similar characteristics in Spain and lessons to be drawn about the successful action taken and mistakes made.

Within the DimeRisk project, therefore, with the support of FUNDACIÓN MAPFRE, an educational plan was drawn up to mitigate seismic risk in Spain, based on previous experience of the earthquake team and the lessons of the Lorca earthquake of 2011. The team has studied the earthquake of Lorca (2)(3), and also earthquakes in Italy and New Zealand.

**Objectives**

The first objective of this project was to analyse the Spanish population’s awareness of and information on seismic risk after the Lorca earthquake and to identify the main shortfalls:

- An assessment has been made of the level of knowledge among different sectors of the population (students, teachers and the public at large) about self-protection measures and also the level of awareness about this natural risk.
- An identification has been made of the main lessons to be drawn from the Lorca earthquake of 2011, such as the most important type of damage observed, population behaviour, etc. These findings can be applied to any Spanish city suffering a seismic episode of similar characteristics.

The second objective is to draw up an education and training plan with different levels and adapted to different ages (primary and secondary school pupils) and different sectors or scenarios (homes and schools). The study concentrated on the population’s level of knowledge and type of behaviour and the main damage observed.

Special care was taken to ensure the proposed activities are practicable in schools and training centres, since the education of school pupils will then filter into homes and the population as a whole (families). Children and youngsters have a much greater receptive capacity than adults and also an ability to internalise concepts. This means they can quickly and efficiently raise awareness levels among their own families and friends and their environment in general. This modus operandi will thus help school pupils and future citizens to build up the minimum necessary expertise and skills to behave appropriately in the face of a destructive earthquake, doing so on the strength of a proper understanding of the whole process, from its geological origin to its effects on buildings.

**Carrying out of the Project**

In pursuit of the posed objectives the project was broken down into three stages:

1. Three surveys were conducted of pupils, teachers and the general population of both Lorca, on the one hand, and Madrid and Seville on the other, to cross-check the knowledge level of populations that have suffered an earthquake against others with no experience of this risk. A total of 491 secondary-school and baccalaureate pupils were surveyed, with ages ranging from 12 to 18 (331 in Lorca and 160 in Madrid and Seville), and also 201 homes (121 in Lorca and 80 in Seville and Madrid). Twenty eight teachers were also surveyed from two secondary schools of Lorca (IES José Ibáñez Martín and IES Ramón Arca: Meca).

An analysis of these surveys then told us the relative perception of the seismic risk, the real knowledge of earthquake-generating sources, seismic geology, etc. and the real knowledge of self-protection measures and mitigation of the seismic risk of students, teachers and the public at large. The Lorca surveys also included questions on the damage
observed, their reactions, the main lessons drawn from the earthquake, etc.

2. Working from the information culled in the surveys on the Lorca earthquake of 2011 and the level of earthquake
knowledge plus the earthquake experience of the work team, the following working plan was then drawn up:

- Available information on the prevention of seismic risk was compiled, updated and homogenised and then brought duly
into line with the characteristics of Spain’s society and education system.
- On the basis of all this information, activities and material were then devised to suit the different education levels and
ages. These activities were geared towards the following educational objectives:
  - An explanation of the seismic phenomenon, setting out the basic earthquake concepts and the geological
    processes they generate.
  - Self-protection. Measures to be taken before, during and after the earthquake.
  - Training and educational procedures. Material for teachers and training teams to teach the public how to respond
    to an earthquake, doing so by means of programmed activities and drills.

3. Finally, the activities and the material with the evacuation and self-protection measures were implemented in schools of
Lorca, Seville and Madrid to check the appropriateness of training levels and the meeting of desired objectives. The schools
were chosen in different Spanish cities to compare the efficacy of the activities on a population aware of the risk, like
Lorca, and others with a lower awareness level.

Results and Discussion

Knowledge of earthquakes and mitigation and prevention measures

Schools
Secondary schools of Madrid and Seville were surveyed to plumb their knowledge of earthquakes and mitigation and
prevention-measures (sample of 160 secondary and baccalaureate pupils). Asked whether they knew how to react to an
earthquake, 49% of pupils answered yes and 51% answered no. This apparently high percentage is misleading, however,
since the ostensible knowledge of measures to be taken is often wrong, drawn essentially from films. When they were
asked about specific measures or whether they would run out of the earthquake-struck building, 80% were unaware of any
self-protection measure, 75% would run out of the classroom and only 24% of respondents had genned up on how to act in
the event of an earthquake. Even basic measures, such as taking refuge under a desk, are not considered to be sound
behaviour by 81% of respondents.

Furthermore, only 2% have ever taken part in an earthquake drill. Pupils therefore have a wrong perception of their own
knowledge about earthquakes and how to react to them and are in fact unaware of the most basic self-protection measures.

As for knowledge of seismic activity, only 24% know what an active fault is and only 19% know that earthquakes are
triggered off by faults and recur periodically in a given zone.

Homes
As for surveyed homes (sample of 80 homes), some of the most significant findings are that 79% would not take basic
earthquake action like crouching under a table or bed; 41% would run out of the building and only 33% have genned up on what
they should do in the event of an earthquake. Knowledge of prevention measures is low and 87% recognise the need for an
education and awareness-raising campaign about this natural risk.

Lorca Schools
The same survey was conducted in Lorca schools, where awareness of seismic risk is perforce much higher, to find out the
level of knowledge (sample of 331 pupils). Particular attention must be drawn to the sterling work carried out by schools
since the Lorca earthquake. Witness the fact that 94% of pupils have taken part in an earthquake drill and 100% report
awareness of some earthquake self-protection measure. Furthermore, 90% of surveyed pupils in Lorca admit ignorance about
when the next earthquake might occur but do know that there will be another one in the future.

Nonetheless, although respondents claim they know how to react to an earthquake since the 2011 quake (99%), only 44%
Lessons learned from the Lorca earthquake of 2011

A survey was conducted exclusively of the pupils of Lorca to find out their reactions at the time to the 2011 earthquake. Significant findings are that only 4% crouched under a table (figure 3a), only 38% waited for the tremor to end before leaving the house and only 5% left the buildings in orderly fashion following evacuation routes. In fact, the feeling of the population after seeing the damage caused by the seismic episode is that they did not react appropriately (76%).

As regards the main damaged identified by teachers in the school (figure 3b) after the 2011 earthquake, they highlight the falling of partition walls/ceilings (25%), cracks (20%), broken wall tiles and falling shelves and cupboards (13%). Finally, 2% did not observe any damage (figure 6).

As for the population in general (sample of 122 homes), although 49% of respondents consider themselves to have acted properly during the earthquake, only 11% crouched under a table and 48% restrained themselves from running out of the building. Twenty percent failed to respect the colour codes for entering damaged buildings. Only 33% shut off gas and water taps after the earthquake. Fifty two percent claim to have kept calm and 46% waited for the tremor to end before leaving the house.

The main mistakes that respondents consider themselves to have made during the earthquake were (figure 4a): running out of the building (43%) and not taking cover (14%), followed by not keeping calm (7%), re-entering the house without expert verification of its state beforehand (4%), evacuating the building with objects and bags (3%) or trying to prevent objects from falling to the floor (2%).

As regards mistakes made by other residents, authorities, security forces, etc. (figure 4b), 25% of respondents think they made no mistakes and 17% believe there was a lack of information and organisation. Eighteen percent believe that the main mistake was to run out of the building and not keep calm and 4% committed the mistake of returning to the house without authorisation.
Figure 4. Main mistakes that respondents consider themselves to have committed during the Lorca earthquake of 2011. And main mistakes that respondents consider to have been committed by authorities, neighbours, firefighters, etc.
The main post-earthquake damage to the houses (figure 5a) involved cracks (40%), fall of non-weight-bearing walls cupboards, heavy objects and wall tiles (19%), fall of ceilings, enclosure walls, etc, (16%) and, to a lesser degree destruction of plant (4%), breakage of pillars (3%), of pipes (3%) and windows (1%)

Respondents consider the most dangerous post-earthquake effects they observed in their homes to be the following: falling cupboards and shelves (24%), objects falling from shelves (17%), falling monitors and televisions (16%) and glass breakage (10%). To a lesser degree they cite falling light-fittings (9%), breakage of wall tiles (3%), falling chimney stack (1%) and falling cornices (1%) (figure 2).

Even after the 2011 earthquake (figure 5a), prevention measures have still not been taken in 26% of Lorca homes. After the earthquake, however, and in view of the main damage suffered by the houses, the measures most widely taken by the population have been to fasten shelves (26%), fasten water heaters (17%), fasten light-fittings (13%), fasten pictures (12%) and fasten television screens (6%). One of the most notable hazards during the 2011 earthquake was falling objects especially onto the bed. After the earthquake 61% of respondents have taken measures and removed objects from above the bed.

On the other hand, 89% of respondents have not yet prepared a small emergency rucksack and water bottle, an important measure for lasting out the hours immediately following the earthquake.

Finally, the survey shows that 93% of respondents now recognise the need for education and awareness-raising on this matter, to learn how to react to an earthquake (figure 5b).
Figure 5. Main measures taken in Lorca households after the earthquake. Significant raised awareness of the need of an earthquake damage-mitigation and -prevention plan.

The most noteworthy finding concerning the knowledge of pupils and the public at large about earthquakes and seismic-risk prevention and mitigation measures can be summed up as false awareness of their own knowledge. When specifically asked about the measures taken in homes or how to react to earthquakes their actual answers are wrong.
Figure 6. Main damage observed in Lorca schools after the 2011 earthquake: falling walls and breakage of wall tiles indoors and fall of ornamentation outside. During the earthquake very heavy objects were seen to fall, injuring people who were running out of the building. The best option, however, would have been to take refuge under desks.

**Resulting Material**

A series of education and training resources have been drawn up to make up for the shortfalls or mistaken training concepts observed and in light of the main hazards and errors identified in the Lorca earthquake of 2011.

A total of 34 education and training activities have been carried out: 6 for infants’ schools, 14 for primary schools and 14 for secondary and baccalaureate schools. Two guides have also been drawn up for primary schools and one for secondary and baccalaureate schools.

The activities and guides are adapted to each educational level but, regardless of the level, all tackle one or more of these three basic earthquake aspects:

- Why do earthquakes occur?
- What is an earthquake and what damage does it cause?
- How can I protect myself from an earthquake?

To answer the first question, activities have been carried out to deal with the internal structure of our planet, plate tectonics, faults and the behaviour of rocks, among other questions. As for the definition of an earthquake, education activities have concentrated on their measurement, magnitude, seismic waves and their location. Lastly, as regards protection from earthquakes, activities cover the prevention and protection measures to be taken by citizens before during and after an earthquake (figures 7 and 8).

**Guide 2: Room safety activity**

Name: ___________________________  Date: ___________________________

Safe or unsafe?

Compare the two rooms. What are the differences? Which is the safer and why?

Which perils are posed by the room in image A?
The guides record all the theoretical questions dealt with in the activities and therefore also respond to the three main earthquake questions. They serve as support for teachers but also aim to bring these questions to wider notice, encouraging pupils to take their classroom-acquired knowledge back to their families and kith and kin.
Summary of earthquake activities

Infant education

1. **Know the Earth (I)**. Under the title «Know the Earth» three activities are proposed for pupils to familiarise themself with the structure of the Earth. In this first activity children will be able to build up a model of the layers forming our planet: crust, mantle and core.

2. **Know the Earth (II)**. This second activity involves the teacher using an orange to show how the outer layer of our planet (the crust) is broken up into pieces (the tectonic plates), which fit together like a puzzle and cause earthquakes when they...
3. **Know the Earth (III).** This third activity involves the pupil representing (drawing or colouring in, according to the age) the various layers of the planet and the crust divided into plates to establish the basic concepts of the structure of the terrestrial globe.

4. **The rucksack friend.** This activity is designed to bring out the importance of always having a survival rucksack on hand in case an earthquake should occur. The idea is to make the children familiar with which objects should be stored in the rucksack and bring home to them the importance of having it near at hand in case of emergency.

   In this activity each child will create the necessary objects, painting them and cutting them out and placing them in a rucksack-representing envelope. At the end of the activity they will be told about the usefulness of each object in the event of an earthquake.

5. **Everything trembles during an earthquake!**

   This activity involves building a simple model of a room, which will then be shaken to show children how objects will behave and the safe areas to take cover. In this didactic fashion pupils will be shown what would happen to objects and persons in a room during an earthquake.

6. **How should we act in the event of an earthquake?**

   This activity involves an earthquake drill to show children 1) how to protect themselves during an earthquake and 2) to leave the building in the quickest possible time and according to proper safety rules.

### Earthquake Dos and Don’ts

**Before an earthquake**
- Identify and remove dangerous elements
- Prepare and familiarise yourself with the evacuation route
- Prepare a water bottle, emergency rucksack and first-aid kit.

**During an earthquake**
- Keep calm and never run out of the building
- Keep away from windows, shelves or zones from which heavy objects may fall, such as pictures, frying pans, saucepans, light fittings, etc.
- Take refuge in safe places (under tables or beds). «Crouch down, take cover and hold on fast».

**After the earthquake**
- Check yourself for injuries. Help as far as possible but otherwise don’t expose yourself
- Don’t use the lift or phones
- Shut off the gas and electricity supply
- Move carefully away from buildings. Without running, make your way to an open area

Earthquake prevention and self-protection guides have also been drawn up for homes and schools, explaining the most important measures to be taken before, during and after an earthquake to mitigate property damage and reduce the number of injuries. These guides include a final summary of the most important measures in the form of Dos and Don’ts and a leaflet (figure 8).

### Primary Education

1. **Know the Earth.** A series of activities of increasing complexity to understand better the earth’s structure. The first activity involves giving pupils an idea of the structure of the Earth with a simple image where they have to fill in the name:
A series of education and training resources have been drawn up to make up for observed deficiencies, within a plan for preventing and mitigating seismic risk in Spain.

2. The enigma of earthquakes. This dynamic activity is proposed for children to put their classroom learning into practice and develop the most general earthquake concepts. Children will be given a puzzle with a tectonic plate image on one side and a simple explanation of how earthquakes occur on the other. They have to put together the pieces hidden in various places to piece together the broken-up explanation.

3. Plate against plate. To understand earthquakes it is essential to know where they occur. This activity explains the shift between tectonic plates and the formation of mountains and volcanos due to these movements. A description will be given of the three scenarios in which they may be triggered: spreading plates (extensional), colliding plates (compressional) and grinding plates (transform). These situations will be represented by six pupils acting out plate tectonics using three different types of materials to simulate the plate boundaries.

4. The Spanish earthquake map. An activity to encourage pupils to learn the Spanish regions with highest seismicity levels. A plain academic explanation of this would not be attractive to young pupils. The proposal here, therefore, is for seismic learning to be combined with creativity, manual dexterity, the coordination of colours, etc. Pupils have to draw up a map of Spain with the seismic regions identified.

5. The ripples of the ground. This activity aims to give a better understanding of the types of seismic waves associated with an earthquake, their order of arrival and even which travel fastest and slowest. This cooperation activity will involve the whole class; this is essential to ensure that the activity is fluid, like a wave movement itself.

6. Earthquake, how strong are you? As they rise up the Richter scale earthquakes liberate more energy and could cause a whole room, a school or even a town or city to tremble. This activity is meant to give children an idea of earthquake magnitude (minor, moderate, great) by means of a simulation in which they themselves act as earthquakes. The children form a group with their arms linked. One member of the class remains outside this group, simulating a seismic movement and trying to separate members, destroying the group.

7. Spaghetti earthquakes. The size of earthquakes is measured by what has become known as the Richter scale. Higher magnitudes (e.g. 7, 8, 9) indicate that the seismic movement is very strong and devastating, while the lower magnitudes (e.g. 1, 2, 3) correspond to very small earthquakes. The Richter scale will be simulated by different packs of spaghetti, which the children will try to break by generating seismic movements of different magnitudes.

8. The emergency rucksack. This activity explains the need of having an earthquake survival kit ready. The children need to have a clear idea of which materials or objects have to be stored in this rucksack. The game consists of making the children familiar with these elements and bringing home to them the importance of at least one household or class member taking charge of this rucksack. This activity will be carried out in two groups, in which each child has an assigned number. Upon hearing their number they have to run out and collect the item the teacher is holding in his or her hand before the corresponding member of the rival group, returning to their group with the won object. These objects will be placed in a rucksack that has previously been given to both teams. The team that achieves most objects and has the best prepared rucksack will be the winner. If there is a draw in objects collected, the tie can be broken by giving a value to each one (figure 9).
9. Wow! I feel dizzy! This is a simple game to familiarise the children with the dizziness they would feel during an earthquake. The children will try to follow a straight line after spinning round a few times. While spinning round they will notice how the floor «is moving» and they will find it hard to walk in a straight line afterwards. This dizziness is similar to what they would feel during an earthquake.

10. What a disaster! This activity shows the damage that could be caused by an earthquake to the furniture, decorative and architectural elements of two known scenarios: the room of a house and the school classroom. The children will be given a pre-earthquake image and a series of cards (a tick and a cross) to identify safe and dangerous earthquake refuge areas, respectively. A post-earthquake image will then show if their choices were correct or not, whereupon they will learn how to protect themselves.

11. The protective desk. This activity is a version of musical chairs, using desks instead of chairs. The desks will be placed in a circle and the children have to move around them while music is being played. Every time the music stops the children have to dive under the tables, protecting themselves with a hand over their head and grabbing one of the four desk legs with the other hand (earthquake self-protection measures). After every round one child is eliminated from the game. It is important to spend some time on this activity since it teaches one of the basic earthquake self-protection measures.

12. Earthquake Control.

This activity aims to encourage control of the natural impulse to run out of a dangerous situation such as an earthquake. Two children simulate a house by standing front on and joining hands. Another child gets inside this “house” as the occupant. The children thus form trios with a fourth one standing outside each time who gives a series of orders for one or the two house roofs to be moved. The occupant him/herself or all the children together thereupon cry out EARTHQUAKE. The pupils have to make these movements and interchanges in a calm and ordered way, since this is the proper way to behave during an earthquake.

13. Earthquake Drill. Drills are one of the most important earthquake-related tasks. Nonetheless, an earthquake drill for children has to be not only a learning activity but also a participative and fun-based activity, especially for the youngest...
children. In this case a story could be told or a rap sequence to teach them how to protect themselves during an earthquake and leave the building as soon as possible in due accordance with known safety rules.

14. Imagining an earthquake. Before or after any intense activity it is always a good idea to carry out a relaxation activity such as guiding children through an imaginary scene. In this particular version of this activity the children are guided imaginatively through an earthquake aftermath, the pupils expressing their feelings, worries and the way they would behave in the event of a real earthquake.

Secondary and baccalaureate schools

1. The earthquake machine. This activity sets out to study earthquake formation on the basis of a simple physical model. Pupils are often hard put to grasp that earthquakes are caused by the elastic behaviour of rocks: the elastic rebound mechanism or stick-slip displacement. The earthquake machine, however, enables them to visualise this physical system and helps them to build/increase/adapt their idea of the seismic phenomenon. They will work collaboratively in small groups to make observations with the model, compile data, represent their findings graphically, check hypotheses and investigate: a) how energy is stored elastically in rocks and is then suddenly released in the form of a seismic movement and b) why some earthquakes are small and others big.

2. Fault roughness: precursors, main event and replicas. This activity shows how a fault rupture occurs and the type of earthquake caused, using a simple physical model to do so: the roughness model. The breakage and slip of a fault plane occurs progressively as some of the rough sticking zones of the surface break up and the plates slip. This process triggers a gradual succession of earthquakes: precursors, main event and replicas. The roughness model (spaghetti resisting the opposed movement of two blocks of wood) enables pupils to grasp this mechanism and the sequence of seismic events.

3. How many small and big earthquakes are there? Gutenberg-Richter relationship.

This activity consists of three exercises to explain the Gutenberg-Richter law to the pupils: i.e., the number of earthquakes in any region will vary by approximately one order of magnitude for each increment in the seismic magnitude of the earthquake. In the first exercise the pupils are given the worldwide annual mean seismicity values to familiarise them with the type of graph to be used for presenting information of this type and to deduce the equation describing the Gutenberg-Richter relationship. The second activity will represent Iberian Peninsula seismicity in the period 1985-2013 for pupils to calculate the constant b and compare it with the results of the world series. In the last exercise the pupils will work with 2013 seismicity to deduce that very long periods of time are needed to determine the seismicity of any region. The idea is for the pupils to arrive at the Gutenberg-Richter relationship by way of discovery learning, albeit counselled by the teacher.

4. Making faults. Rocks, at typical temperatures and pressures of the part closest to the surface of the earth, behave in a fragile manner. In other words, they fracture if subjected to a strong force. These breakage planes are called faults if a movement of surface rocks occurs above them. Earthquakes are triggered precisely by fault slips. In this activity pupils will learn about the different types of faults produced by the various types of forces and plate movements and their relation to earthquakes.

5. Squares against triangles: building resistance on an earthquake testbed. Earthquake damage is often the result of improper building construction or the failure to adopt earthquake-resistant measures suitable for the area they are built in. Non-observance of these measures is one of the main causes of personal harm. Earthquakes of similar magnitudes cause bigger catastrophes in some areas than in others. Why is this? This activity helps pupils to learn and identify constructive elements that make buildings safer in the event of earthquakes with very high horizontal oscillations.

6. Distance of the building from the epicentre. Earthquake damage is often the result of improper building construction for the area they are built in. Packing too many buildings into insufficient space and failure to observe basic considerations in relation to the geographical area concerned are two of the most harmful failings. Building resistance also depends on their oscillation and their distance from the epicentre. Earthquakes of similar magnitudes cause bigger catastrophes in some areas than in others. Why is this? This activity shows pupils how earthquake-produced terrain vibration affects buildings (oscillation periods), leading to different behaviour in each case. The pupils are also grounded in the theo
Two guides have been drawn up for different age brackets of school children. These give pupils a basic knowledge of earthquakes and show them how to confront them.

7. A jelly earthquake: type of substrate and local topography. The type of substrate over which a building is raised is a fundamental factor in its earthquake resistance thereafter. When the earthquake hits, soft substrates oscillate at a higher wavelength and for a longer time than rocky soils, with the concomitant danger to buildings, especially the higher ones. Another damage-increasing factor in buildings is the topographic effect. Wavelengths broaden on high ground so vibration on a hilltop is higher than at the bottom of the hill. Both factors together may also have a synergistic effect. In this activity, we will be looking at these factors.

8. Conjugate and parallel fractures. Propagation of seismic waves generates wall fractures in line with terrain movement. One of the wall effects of building vibration is the formation of conjugate (X-shaped) or parallel fractures. These are produced by cyclical movements induced by seismic waves. The formation of cross-shaped fractures is typical of walls running parallel to the direction of the movement, while parallel fractures are typical of walls running perpendicular to the direction of terrain movement. In this activity, pupils will learn the Earthquake Archaeological Effect (EAE) and how its orientation indicates the direction of terrain movement during the earthquake.

9. Effects of faults on linear constructions. The presence of active faults in a zone crossed by a linear construction (road, railway, oil pipeline, power line, walls, etc.) could seriously affect these constructions in the event of fault rupture during the earthquake. Due to the fact that these constructions intersect the fault at a given point, damage will be localised and prevention measures can be taken against it. This activity will display the effects that might be produced in linear constructions by any fault rupture, evaluating the damage that might be caused and any damage-avoiding construction measures that might be taken.

10. SOS. Dangers of an earthquake. In an earthquake the sudden liberation of elastic energy in the form of seismic waves is rarely the direct cause of deaths and injuries. Most victims are the result of falling rubble, breakages or falling objects and even human imprudence and panic. This activity will help pupils to identify dangers associated with elements forming part of the school building (shelves, books, windows, etc.) whenever an earthquake occurs and thus mitigate associated risks and forestall panic.

11. Towards a safe home. In an earthquake the sudden liberation of elastic energy in the form of seismic waves is rarely the direct cause of deaths and injuries. In fact, the safest place during an earthquake is open country. Most victims are the result of falling rubble, breakages or falling objects and even human imprudence and panic. This activity will help pupils to identify dangers associated with non-structural elements forming part of their home (furnishings, decorative items, windows...) whenever an earthquake occurs and thus be well informed and prepared for avoiding risk situations.

12. Role play: the evacuation. To reassure pupils and help them react correctly to an earthquake, it is important for them to be aware that, whenever an earthquake occurs, wide-ranging safety arrangements swing into action to help them and to bring the situation back to normal. This activity aims to inform pupils about the various emergency forces that intervene immediately after any seismic event and show them the activities carried out by each one. This will be done by means of role play as a form of fun learning about how they should react in any similar situation in the future.

13. The scream. An earthquake poses a challenge not only to our buildings but also to our response capacity when faced with a terrifying situation. It is therefore crucial to know how to react in situations of fear and stress. The activity involves a terrifying-scream competition, with the idea of bringing home to pupils how important it is to know how to react to an emergency situation. There will also be some debate about panic and terror reactions in extreme situations, with a reflection of whether such behaviour is helpful or unhelpful.

14. How should we prepare ourselves for an earthquake? Survival container and rucksack. One of main means of prevention against earthquake effects is to prepare kits with basic necessities for the four days after the catastrophe: survival container and rucksack. In this simulation activity the pupils will prepare these two types of kits. They will find out that the rucksack should contain articles that someone might need during one day, so it should be easily portable and should be picked up upon leaving the building after the earthquake. It therefore has to be kept in an accessible place. As for the container they will learn that it should contain the household products that are likely to fall short in these first
aftermath days. This supply can then be dipped into when the authorities consider the home as safe to return to. It should be kept in a cupboard, store or larder. The last part of this activity will be carried out in homes, allowing the pupils families to find out about this earthquake-prevention measure.

Summary of earthquake guides

Primary Education

Two guides have been drawn up for primary schools, one designed for pupils aged 6 to 9 (Know our Earth. Earthquake guide for pupils of the 1st, 2nd and 3rd primary years) and another targeted at pupils aged 9-12 (Know our Earth. Earthquake guide for pupils of the 4th, 5th and 6th primary years). They provide a basic knowledge of earthquakes, describing why the Earth has earthquakes, what they are and how we should behave to protect ourselves if they occur.

Secondary Education, baccalaureate and support for teachers

One guide has been drawn up targeted at teachers (Notes on earthquakes) setting out the main earthquake concepts such as magnitudes, faults, seismic waves, etc. This could be read independently or as support before the activities are carried out by the teacher. It has been worded in such a way as to be readable directly by pupils and any member of the public who is interested in earthquakes.

Acknowledgements

This research has been financed by FUNDACIÓN MAPFRE (Research grants 2012).

References


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