Mónica Amaral Ferreira
Beatriz Zapico Blanco (coords.)

EDUCATIONAL GUIDE

WHY DOES THE GROUND

SHAKE?

BOOK REVIEW

Editorial Universidad de Sevilla

SUMARY

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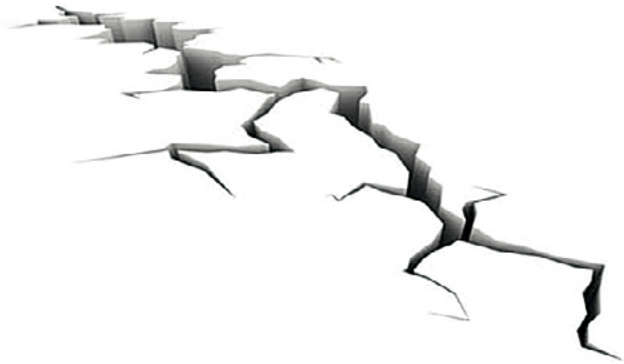
WHY DOES THE GROUND SHAKE?

PERSISTAH Project
(Projetos de Escolas Resilientes aos SISmos no Território do Algarve e de Huelva)



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WHY DOES THE GROUND SHAKE?

SUMARY

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SUMARY

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SUMARY

SUMARY

Sumary

Chapter 1. Introduction

1.1. EDUCATION FOR RISK REDUCTION

PERSISTAH (*Projectos de Escolas Resilientes aos SIsmos no Território do Algarve e de Huelva*) is a Portugues-Spanish cross-border project, financed by INTERREG, which proposes the development of diagnostic, validation, management and rehabilitation instruments for primary school buildings. The project also involves the development of support material for teachers, in line with the goals of the National Platform for Disaster Risk Reduction of the National Commissions of Civil Protection of Portugal and Spain.

Another goal of the PERSISTAH project is to increase the resilience of the communities through education and risk communication. The educational community can be trained as involved citizens, who are aware of the risk.

Regarding prevention and seismic risk mitigation, is important to inform and educate the school community about the existence of this risk through training at schools, the identification of the potential risks inside and outside buildings, the implementation of measures which could be taken for structural and non-structural risk reduction and conducting evacuation drills in order to learn how to behave in case of an earthquake.

1.2. ABOUT THE EDUCATIONAL GUIDE

The educational guide "Why does the ground move?" is designed to support the training of primary school teachers, instructors and technicians, who want to improve their knowledge and develop activities about seismic and tsunami risk. The contents and information of this document come from researches carried out at present, and also as the continuation of other projects in which the author has participated, such as the game "Treme-Treme" (<http://www.treme-treme.pt/>), which was started with the European project UPStrat-MAFA (2013), and several materials (games, videos and practical guide) for risk communication and education, in the scope of the KnowRISK project (2017).

The development of this educational guide is based on the guidelines contain in the Referencial da Educação para o Risco (RERisco, 2015), which is organized for educational levels. These contain the themes and subthemes to be addressed for all risks (natural and technological) and goals for different school levels, as described in Figure 1.

1st Cycle of Primary School

SUBJECT: EARTHQUAKE

— Know the causes and susceptibilities:
  - Know the concept of seism.
  - Know the Richter magnitud scale.
  - Locate the most earthquake prone geographic areas.

— Differentiate the main efects:
  - Know the primary seismic effects.

— Understand self-protection measures:
  - Identify suitable measures in case of earthquake.
  - Be able to comply with / apply self-protection measures.

SUBJECT: TSUNAMI

— Know the causes and susceptibilities:
  - Know the tsunami concept.
  - Locate the most susceptible geographic areas of tsunamis.

— Differentiate the main effects:
  - Know the different direct effects of a tsunami.

— Understand self-protection measures:
  - Know the signals and warning of the eventual arrival of a tsunami.
  - Be capable of to apply self-protection measures.

Extract from *Referencial da Educação para o Risco.*

Figure 1. Organization of the Risk Education Framework.

In order to fufill the aforementioned goals, educators need to have at their diposal educational resources for the first and continuous training of school community. Due to the lack of this material for the Iberian Peninsula, a set of educational material, which can be used as orientation tool, has been developed within the PERSISTAH project.

This material can be used in three learning types (formal[1], no-formal[2] and informal[3]), in order to facilitate the interconnection between subjects and lessons which are tackled in the primary school curriculum.

The goal is to teach the seismic phenomenon and the reduction of risks to teachers and children in a creative, pedagogical and playful way, integrating various activities that promote individual and collective participation. In this way, children will develop a culture of safety, which can be applied to other daily life moments, encouraging them to solve problems and promoting connections with real life.

This document is divided in two parts which contain a set of resources and instruments at the service of teaching:

- Educational guide for teachers.
- Activity suggestions (educational games, puzzles, models and maps, among others) so that teachers and students can explore the subject in a practical and creative way, based on critical thinking and experience.

The educational material diversity improves the number of pedagogical and didactic options for the teacher, stimulating and helping to capture the attention of the children. The teacher will be responsible for selecting and managing the materials, according to the characteristics, needs and interests of the children, the content of the curriculum, the nature of learning and the skills he or she would like to promote (Correia, 1995; Graells, 2000).

This educational guide has been tested and implemented since October 2018, in preschools (5 years) and primary schools (6-12 years). The activities carried out in the school period of 2018/2019 and 2019/2020 in the San Roque museum in Lisbon were:

1. *"The earth shakes! It is an earthquake!"* and
2. a workshop organized for families, in collaboration with the Higher Technical Institute and the Church and Museum of San Roque (*"If I were… Structural Engineer"*);

1. Formal education: it is developed in the Educational System (schools and universities), where the student follows a predetermined program, which is similar to other students attending the same institution (Chagas, 1993).

2. No-formal education: it is carried out outside the Educational System and it is done by museums, media and other institutions that organize events of various types, such as open courses, fairs and meeting.

3. Informal education: it happens throughout live, spontaneously in the daily life, through conversations and experiences with family, friends, and other person.

contributing to non-formal scientific learning. The material was also used for an experimental classroom activity, with 20 students of first year of primary school of the Jardim-Escola João de Deus da Estrela (in Lisbon, Portugal), in June 2019.

The collaboration of other cultural entities apart from the school, such as museums, universities and science centers are essential to get the most out of these projects.

This educational guide could be of interest to other public, such as future primary school teachers, postgraduate students and authors of teaching resources.

SUMARY

Chapter 2. What is an earthquake?

The earth is the planet where we live. It has a spherical shape, which is formed by many layers, like a boiled egg. We can use playdough (Figure 2) or a boiled egg (Figure 3) to represent the internal structure of the Earth.

Figure 2. Models of the internal structure of Earth, using playdough of several colours (right image: <http://cienciasideiaxxi.blogspot.com>).

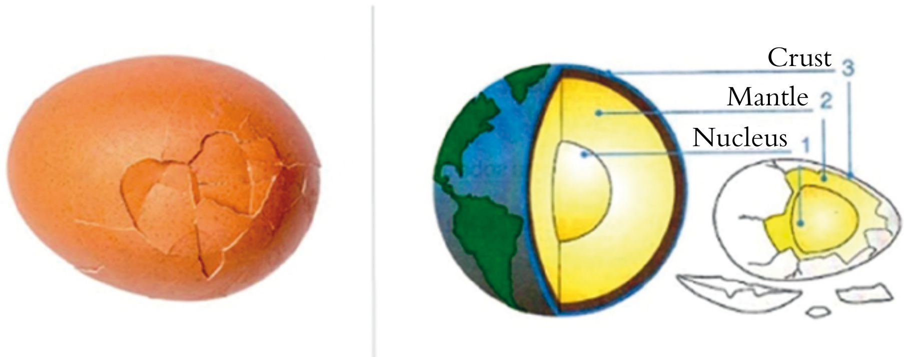


Figure 3. Structure of the Earth. Example using a boiled egg.

If we cut a boiled egg (the Earth) in two, we found the **nucleus** (or yolk) inside. The nucleus is slightly larger than the moon and extremely hot. The nucleus is composed by iron, nickel and other metals.

The egg white corresponds to the **mantle**, which is a cap with almost 3 000 kilometres of very dense rock, rich in iron and magnesium. Magma is formed when temperatures within the mantle are very hot. When a volcano erupts, the magma rises and overflows.

The Earth's **crust** (where we live), which forms the continents and the sea-bed, is the most external layer. It is composed by several huge pieces (similar to the pieces of a cracked eggshell), which fit like a puzzle. Their name is **tectonic plates (or lithosphere)**.

Heat causes movement in the mantle and, consequently the tectonic plates move. When they clash with each other cause earthquakes (seisms or tremors).

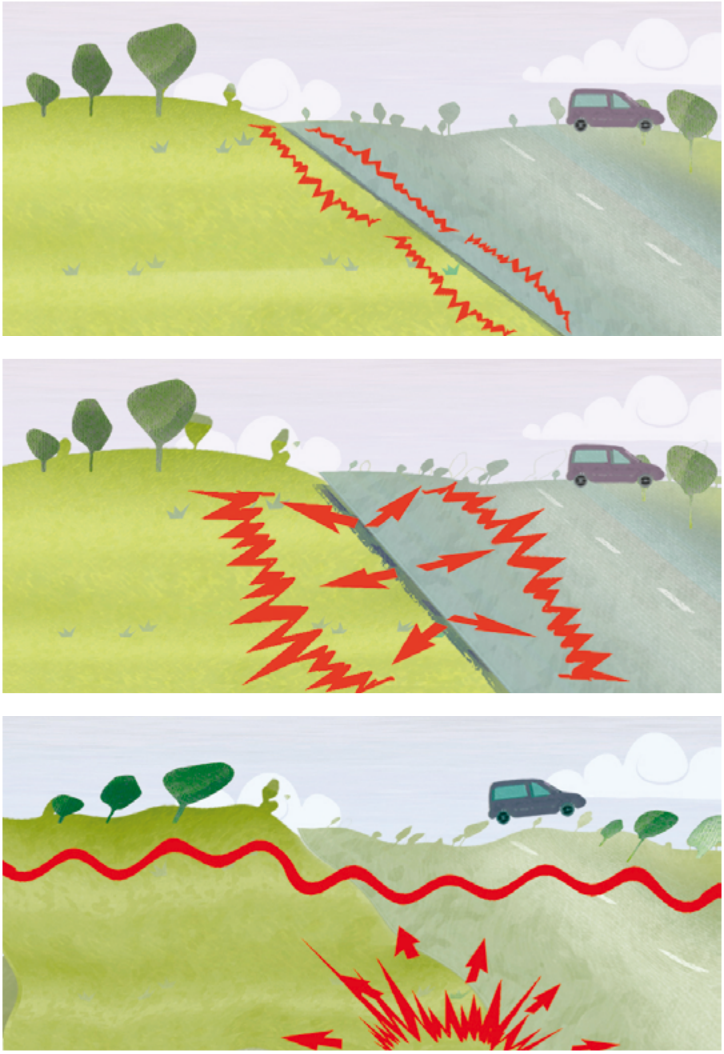
There are around 20 plates along the surface of the Earth, which move continuously and slowly over each other. An earthquake occurs when the plates approach or separate (example of the hands / knuckles, Figure 4).

Imagine your hands as "tectonic plates" and your knuckles as "plate edges". Bring your hands together. The more you push your knuckles together, the more difficult the sliding movement of your fists will be, and the larger the pressure you feel in your knuckles. If you keep pressing for a while, a "plate" will slide, releasing the accumulated energy in your hands. It is an earthquake.

Figure 4. Tectonic plate collision representations (Mónica Amaral Ferreira and Hugo O'Neill).

You can also use a pencil to show the phenomenon. Hold a pencil horizontally. Apply force in both pencil ends, pushing down, and you will see that the pencil forms a curve. If you keep pushing, the pencil breaks in half, releasing the stress you put on it. The Earth crust behaves in the same way. When the crash occur, the tension is released and the energy moves through the ground in the form of waves, which we can feel as an earthquake (Figure 5).

SUMARY



Plates crash.

When the stress reaches a limit, the fracture appears and the energy is released.

The vibration spreads across the ground in all directions. It is an earthquake.

Figure 5. Explanation "the ground shakes" (Hugo O'Neill).

The plate boundaries are very active areas in terms of earthquakes and volcanoes. Depending on the plate movement, the boundaries (or limits) between them can be: divergent, convergent or transform (Figure 6).

SUMARY

Divergent   Convergent   Transform

Figure 6. Chocolate snack representing plate boundaries motion (Mónica Amaral Ferreira and Hugo O'Neill).

— **Divergent limit / boundaries**: when two plates are moving apart. Most active divergent plate boundaries occur between oceanic plates and exist as mid-oceanic ridges. The best-known example of a divergent plate boundary is the Mid-Atlantic Ridge, an undersea ridge that runs under the Atlantic Ocean and the Arctic Ocean. In some points of the ocean, it is possible to see elevations of this Atlantic ridge, forming island. Among such points are Iceland, Bermudas and the Azores, where the highst point of the ridge is located, at Pico Island (2351 meters of altitude).

— **Convergent limit / boundaries**: when two plates are colliding and cause subduction (Figure 7), i.e., when one plate (oceanic crust) slides under the other (continental or oceanic plate). Earthquakes and volcanoes are common around convergent limits. Most of the tsunamis are caused by the earthquakes generated in the subduction area.

— **Transform limit / boundaries**: when two plates slide parallel to eachother, in opposite directions.

Earthquakes can be originated inland or offshore. If a strong earthquake (magnitude greater than 7) occurs, and we are near the coast, there is risk of tsunami, which is a giant wave that can be the height of a building and reach the speed of an airplane (see chapter "What generates a tsunami?"). In the Iberian Peninsula both earthquakes types can take place, which means that there is also a risk of tsunami.

SUMARY

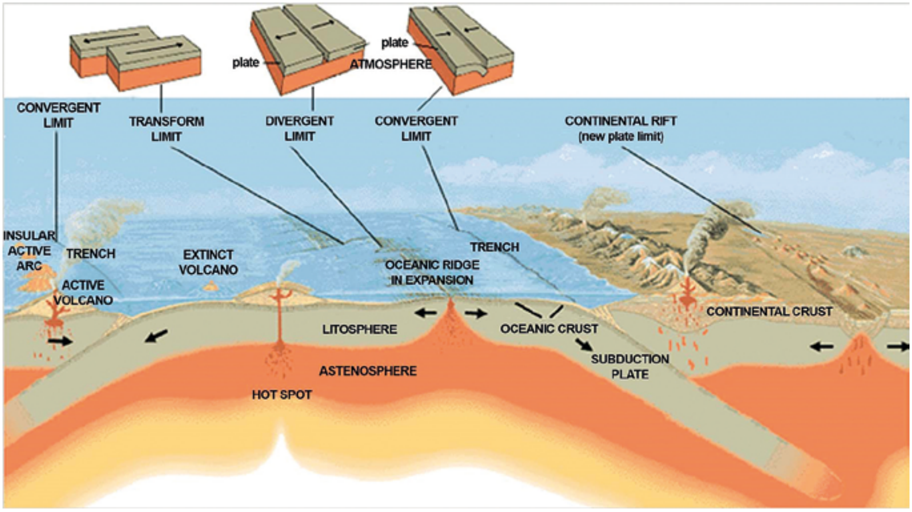


Figure 7. Example of fault, subduction, trench, oceanic crust and continental crust (source: <http://www.lneg.pt/CienciaParaTodos/edicoes_online/diversos/guiao_tectonica_placas/texto>).

At the end of this chapter, teachers could propose the following activities to their pupils:

Suggested activities	
The Earth planet model in playdough	Figure 2
The boiled egg	Figure 3
Chocolate snack representing the plates boundaries	Figure 6
Puzzle of the tectonic plates	Page 49

SUMARY

Chapter 3. How do we measure earthquakes?

More than one million earthquakes take place on Earth every year. Most of them are of very low magnitude, and we can not feel them. In Portugal, around 25 earthquakes per year are felt, and in Spain, around 12 earthquakes with a magnitude greater than 3 take place.

Earthquakes can be weak, but they can also be very strong. How do we measure earthquakes? The instrument which records the seismic waves that move through the ground is called **Seismograph**. Movements are recorded in seismographs, which generate graphics called seismograms. Seismologists can obtain information from seismograms, such as the location of the hypocentre and the magnitude of the earthquake.

The **hypocentre**, or underground focus point of an earthquake, is the point inside the Earth (lithosphere) where the seismic movement starts, i.e., where the fracture takes place. The **epicentre** is the projection of the hypocentre in the Earth's surface, where the earthquake is felt most intensely and the largest damages in buildings and people are produced (Figure 8).

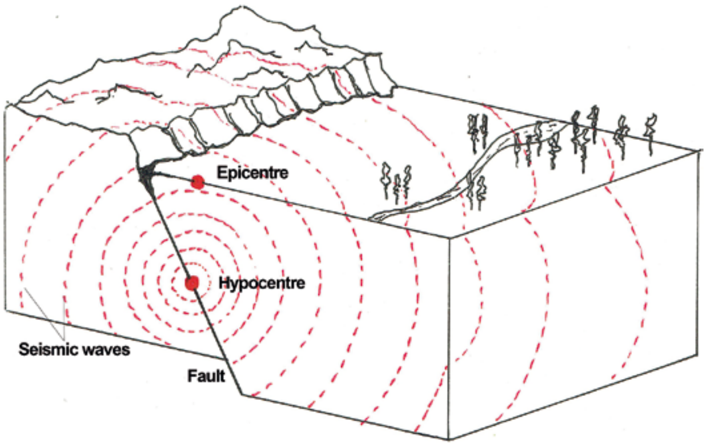


Figure 8. Hypocentre *vs.* Epicentre (Emilio Romero Sánchez).

3.1. RICHTER SCALE

In seismology, two scales are used to measure an earthquake: Ritchter and Mercali. The Richter scale, which was created in 1935 by the scientist Charles Francis Richter, measures the magnitude (released energy) of an earthquake. The Ritcher scale is not a linear scale, it is a logarithmic one; that is, multiplied by 10. Each number represents a magnitude 10 times greater than the previous one. For example, magnitude 5 is 10 000 times larger than magnitude 1 (Figure 9).

Figure 9. Richter is a logarithmic scale (Emilio Romero Sánchez).

For the soil to move ten times more, the amount of energy released needs to be 32 times higher (Figure 10). That is, an increase of one step in the logarithmic scale of magnitude corresponds to $10^{1.5} \approx 32$ times more energy released. An increase of two steps corresponds to $10^3 = 1\,000$ times more energy. Thus, an earthquake of magnitude $M_w = 7$ releases 1 000 times more energy than one of magnitude 5, and approximately 32 times more than one of magnitude 6.

Figure 10. Released energy (Emilio Romero Sánchez).

SUMARY

Just to give you an idea, the Hiroshima bomb was equivalent to an earthquake of magnitude 6, and the meteorite which exterminated the dinosaurs, was equivalent to an earthquake of magnitude 13. The largest recorded earthquake was of magnitude 9,5 and took place in 1960 in Chile. There is not a theoretical limit for an earthquake magnitude, but it is estimated that an earthquake with a magnitude 15 would destroy the planet, dividing it in two.

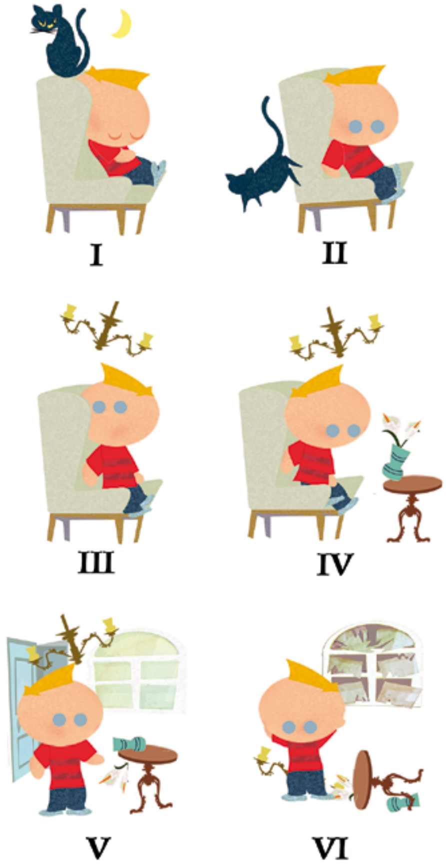
Earthquakes with a magnitude 5 or above, can cause minor to moderate damages in vulnerable buildings, while most buildings would suffer severe damages or even collapse when hit by an earthquake of magnitude larger than 7 (Figure 11).

Figure 11. What is the effect of earthquakes on buildings? (Hugo O'Neill).

3.2. MERCALLI SCALE

The Mercalli scale was created in 1902 by the Italian seismologist Giuseppe Mercalli. It is used to measure intensity, that is, the earthquake effects in the population and buildings. It is a scale of 12 degrees (in roman numbers) where each degree represents the earthquake severity, from imperceptible to totally catastrophic (Figure 12).

SUMARY



MODIFIED MERCALLI INTENSITY SCALE (Abbreviated)			
I	NOT FELT	Not felt by humans.	
II	WEAK	Felt only by a few persons during sleep, especially on upper floors of buildings.	
III	WEAK	Felt indoors. Pending objects swing.	
IV	LIGHT	Dishes, windows, doors disturbed; Standing motor cars may rock slightly.	
V	MODERATE	Felt indoors by many. Dishes, windows, doors disturbed; Standing motor cars rocked noticeably.	
VI	STRONG	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned.	DAMAGE TO BUILDINGS
VII	VERY STRONG	It is difficult to remain standing. Felt in moving vehicles.	
VIII	SEVERE	Affects driving vehicles.	PARTIAL
IX	VIOLENT	Panic general. Conspicuously cracked ground	
X	EXTREME	Large landslides. Slightly bent railroad rails.	DESTRUCTION OF BUILDINGS
XI	EXTREMELY DANGEROUS	Railroad rails greatly bent. Pipe lines tore apart, or crushed.	
XII	CATASTROPHIC	Few, if any, structures standing. Wide cracks in ground. Waves seen on ground. Objects thrown up into air.	TOTAL

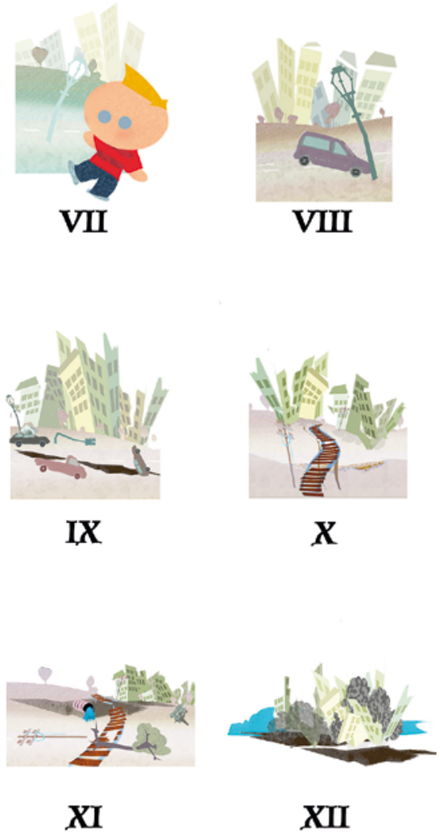


Figure 12. Modified Mercalli scale (Hugo O'Neill).

SUMARY

The following list sumarizes the most relevant earthquakes in history:

1. Valdivia, Chile, May 22, 1960 (magnitude 9,5). It caused around 1 600 deaths in Chile, together with a tsunami which caused death and damages in places as far as Hawai, Japan and Filipinas. Two days after the earthquake, the Puyehue volcano erupted.
2. Alaska, March 28, 1964 (magnitude 9,2). The earthquake was felt mainly in Alaska, as well as in some places in Canada. This earthquake triggered a tsunami which caused damages in locations as far as Hawai.
3. Sumatra, Indonesia, December 26, 2004 (magnitude 9,3). The second largest earthquake ever recorded, after the earthquake in Chile in 1960. The earthquake and tsunami caused 335 000 deaths and 150 000 students lost their school buildings. Few hours after the quake, the tsnumai devasted the east coast of Thailand, as well as Sri Lanka, India and the west cost of the Maldives.
4. Tohoku, Japan, Mars 11, 2011 (magnitude 9,0). The tsunami caused a nuclear disaster in Fukushima, which produced the indefinite evacuation of thousands of people, in a 20 kilometers radius. Around 200 school buildings were destroyed and more than 700 were significantly damaged by the tsunami.
5. Kamchatka, Russia, November 4, 1952 (magnitude 9,0). This earthquake generated a tsunami which caused widespread damages in the Hawuaiian islands. The tsnunami arrived in Alaska, Chile and New Zeland.
6. Maule, Chile, February 27, 2010 (magnitude 8,8). This earthquake and tsunami killed at least 521 people and wounded 12 000. More than 800 000 people were evacuated. The earthquake and tsunami destroyed or damaged more than 3 000 schools in Chile, affecting up to 1,25 millon students. A small tsunami crossed the Pacific Ocean, causing damages in ships located as far as in San Diego, California.
7. Ecuador Coast, January 31, 1906 (magnitude 8,8). The earthquake triggered a tsnunami which caused between 500 and 1 500 victims in Ecuador and Colombia. The tsunami hit the west coast of the United States (San Francisco), Hawai and Japan. It took the tsunami about 12 hours to cross the Pacific and get to Hilo, Hawaii.
8. Portugal, November 1, 1755 (magnitude 8,7-9,0). The earthquake was felt strongly in Lisboa, Algarve, south of Spain and Marroco. It was also felt in the Azores although without damages. Damages in buildings were however observed in Ponta Delgada (San Miguel), Angra do Heroísmo and Praia da Vitória (Terceira), Madeira and almost all Europe. The total number of victims is very uncertain, with estimates ranging from 20 000 to 40 000 people.

SUMARY

Chapter 4. What generates a tsunami?

What happens if an earthquake takes place at sea? When this occurs, the sea moves abruptly and rises, mobilizing a large amount of water. It is the first wave of the tsunami. A tsunami (*harbor wave* in Japanese), is a very fast and low wave in the open sea. As it approaches the coast, when the depth gets shallower, the wave loses speed and increases its height (up to 50 m!), conserving its total energy. A tsunami is a devastating event, having a great social, economic and environmental impact.

Figure 13 shows how a tsunami is generated. The subduction zone is a long and narrow area where one tectonic plate descends below another. Due to friction, and to the fact that the plates move slowly most of the time, the subduction zone is normally blocked. In this way, energy accumulates while the plates deform. When the accumulated energy exceeds the frictional force between the two plates, there is a sudden relative movement between them, along the subduction plane, which releases a huge amount of energy. The released (potential) energy is transformed into motion (kinetic energy). When this happens, the seabed may move abruptly, and this movement is transferred to the overlying water column, generating the tsunami.

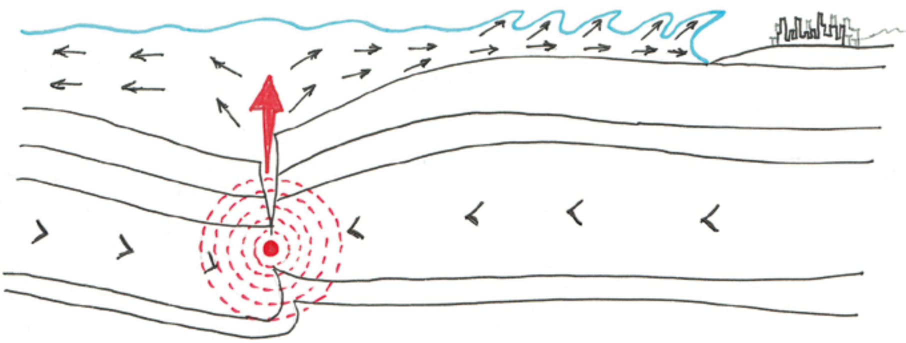


Figure 13. Tsunami generation (Emilio Romero Sánchez).

It is important to recognise the natural warning signs and act quickly (Figure 14):

If you feel a strong earthquake or tremor, and you are near the coast, a tsunami could follow.

As a tsunami approaches shorelines, water may recede from the coast, exposing the ocean floor, reefs and fish. You may also hear a loud "roaring" sound similar to that of a train or jet aircraft.

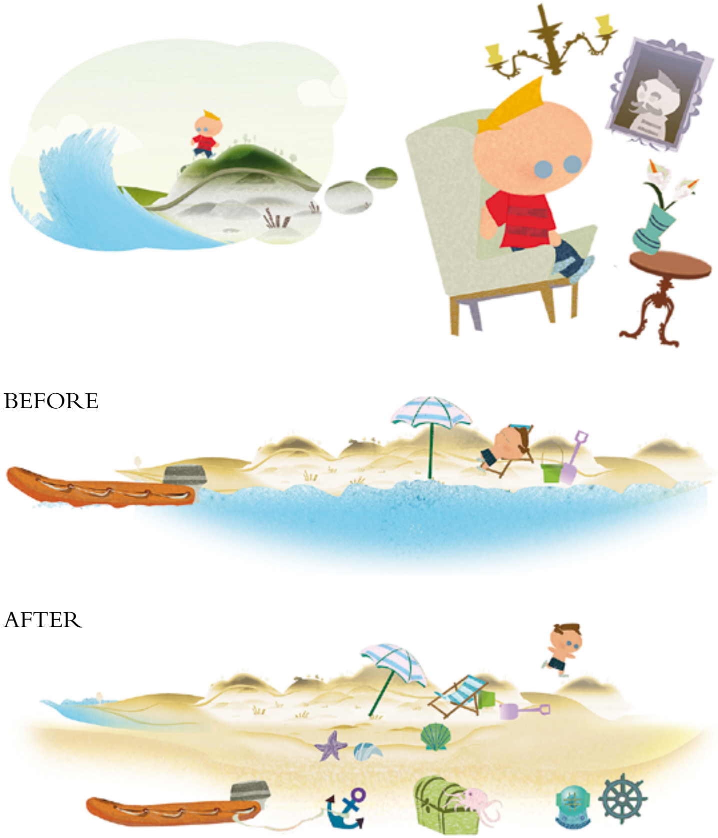


Figure 14. Tsunami natural warning signs (Hugo O'Neill).

At the end of this chapter, teachers could propose the following activities to their pupils:

Suggested activities	
Troubles always come in threes	Page 52
Locate earthquakes around the world	Page 54
Locate tsunamis around the world	Page 56
Word search	Page 72

SUMARY

Chapter 5. Are we in danger here?

Three factors determine, together, the seismic risk:

1. The seismic hazard level, that is, the probability of suffering the natural phenomena related to the occurrence of earthquakes, such as ground motion, liquefaction, landslides, etc. of a specific location. The seismic hazard is quantified in probabilistic terms, and it indicates the probability of a certain seismic parameter (intensity, acceleration or speed) exceeding a determined level in a given period of time.
2. The number of people and buildings exposed to the hazard.
3. How prepared structures and population are to withstand the hazard, or their vulnerability.

The Iberian Peninsula, in average, is characterized by a moderated seismic hazard, compared with other regions in the world. However, the south of the peninsula shows an important seismic action, due to the convergence of the Euro-Asiatic and African tectonic plates, which stretches along the Mediterranean see and the Strait of Gibraltar, reaching the Azores Islands.

Due to the proximity of this convergence, the Iberian Peninsula has gone through a good number of high magnitude earthquakes, with catastrophic consequences. Among them, the 1755 and 1969 earthquakes can be highlighted (Sá, Morales-Esteban & Durand Neyra, 2018).

The seismic hazard in Spain is defined through a map (Figura 15) present in the *Norma de Construcción Sismorresistente or NCSE02*. The NCSE02 is the mandatory code in Spain, regarding the construction of structures under seismic loads.

This seismic hazard map shows the area of the country coloured in different tones, indicating the combination between the magnitude of the expected earthquakes and their frequency for that specific area.

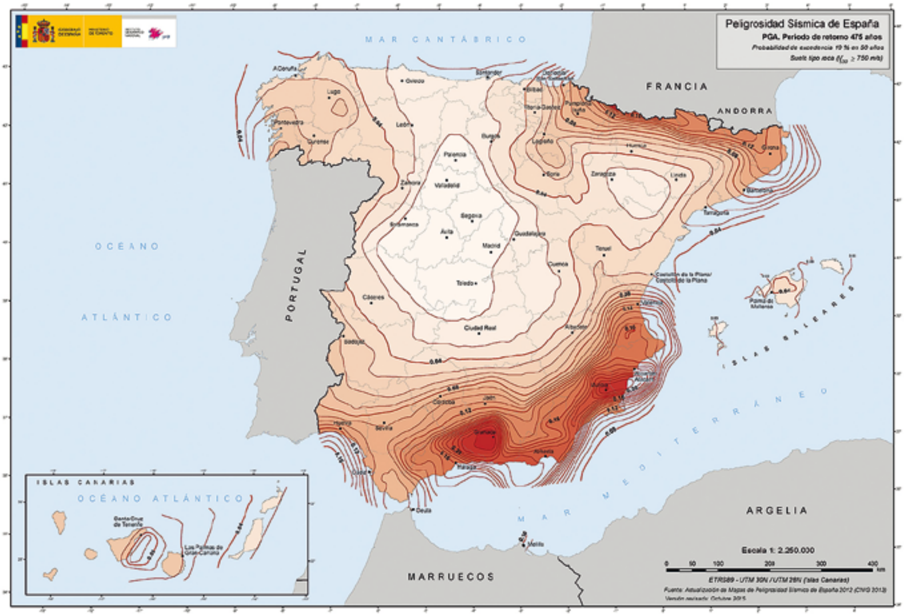


Figure 15. Spanish seismic hazard map (*Norma de Construcción Sismorresistente*, NCSE-02).

The region of greatest seismic hazard in the Iberian Peninsula is located at the southeast, englobing Murcia and the Sea of Alboran (in dark red in the map in Figure 15). This region features **frequent** earthquakes ranging from **low to moderate magnitude**. For these reasons, the majority of studies and seismic risk and vulnerability analysis in the Iberian Peninsula focus on this region. The most relevant seismic event registered recently in the Iberian Peninsula was precisely the Lorca earthquake (Murcia) in 2011. The energy released by this earthquake was equivalent to an atomic bomb!

However, the Algarve-Huelva region, situated in the southwest of the peninsula, is characterised by **high magnitude** earthquakes (they release high amounts of energy) which are expected to take place **less frequently** (Morales-Esteban, Martínez-Álvarez, Scitovski & Scitovski, 2014). This is due to the proximity of this region to faults which accumulate energy for long time periods before they are triggered (Azores-Gibraltar, Marqués de Pombal, San Vicente). The less frequent occurrence of the event encourages that earthquakes, although very important, do not last in the collective memory of the population of these regions.

Although the risk of tsunami is not very high in Spain, the southwest cost of the Iberian Peninsula is one of the most exposed areas of Europe, given the above mentioned fault systems.

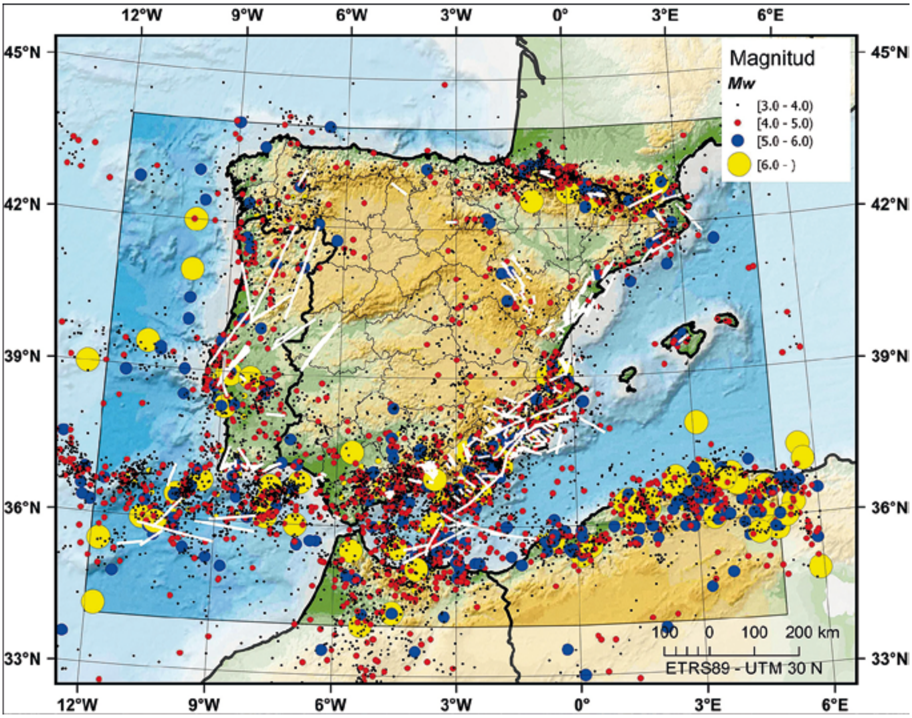


Figure 16. Quaternary active faults in the Iberian Peninsula and magnitude of earthquake.

The Portuguese territory is divided in four seismic zones, depending on the hazard level (Figure 17): reduced, low, moderated and high. As can be observed, the southern area of mainland Portugal is the area with the highest hazard. The Fores and Corvo islands, together with the Madeira archipelago, present a reduced hazard level.

In Portugal, the tsunami hazard, as the seismic one, is real. The Algarve, the Alentejo coast, Setúal, Sesimbra and the regions of Almada, Alcochete, Lisbon and Estoril coast are the most exposed. Among the most catastrophic tsunamis that hit the Portuguese region, one could highlight that of August 24, 1356; that of January 26, 1531, which flooded Lisbon and the Tagus Valley; and that of November 1, 1755, with waves reaching 30 m in height and which caused between 20 000 and 40 000 fatalities. All these tsunamis were generated by earthquakes, with the epicenter probably located in the Gorringe area, that is, in the sea southwest of Cape St. Vincent.

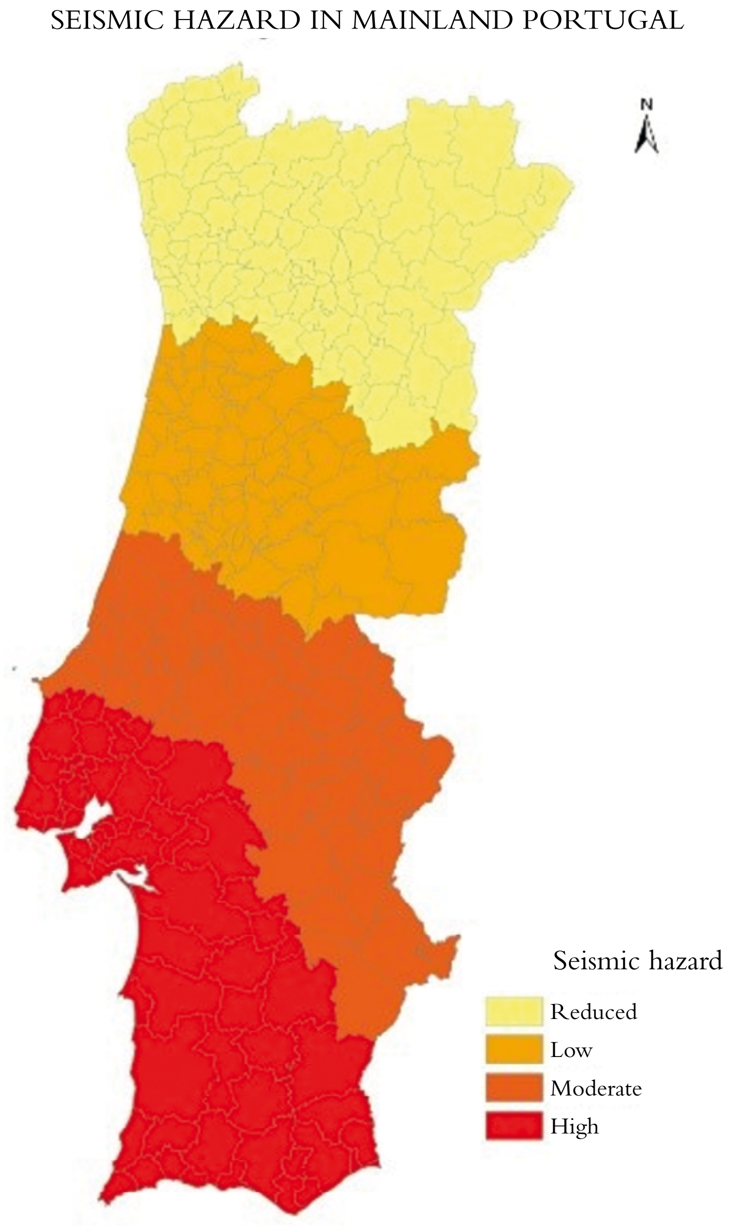


Figure 17. Seismic hazard in mainland Portugal (*Regulamento de segurança e ações para estruturas de edifícios e pontes. 1983*).

5.1. MOST DESTRUCTIVE EARTHQUAKE AND TSUNAMIS IN THE IBERIAN PENINSULA

The following events shaped the seismological history of the Iberian Peninsula:

— September 22, 1522. With an estimated magnitude of 6,5, this earthquake had its epicentre in the area of Algham, Almería. It affected severely the city of Almeria, and caused important damage in nearby towns, such as Vera, Baza, Guadix or Ugijar (Granada). It is considered the most damaging seism in the Spanish history.

— January 26, 1531. This quake hit the centre of mainland Portugal, specially the region of Lisbon. The epicentre was located, probably, in the Benavente region (fault of the inferior Tajo valley). Its magnitude is believed to be 6,5, and some agitation was felt in the Tajo waters.

— October 9, 1680. Known as the 1680 Malaga earthquake, it had its epicenter west of the city of Malaga and a maximum intensity of VIII-IX. The shake was felt in the city of Malaga and in other cities in central Spain, such as Toledo, Madrid and even Valladolid, more than 500 km away.

— December 27, 1722. This seismic event caused great damage (human and material) from cape S. Vicente to Castro Marim affecting Tavira, Faro and Loulé. The epicentre was located offshore, and local tsunami was generated.

— November 1, 1755. Also known as the Lisbon earthquake, this is the largest seismic event ever documented. It was strongly felt in Lisbon, the Algarve, south of Spain and Morocco. It was also felt in Azores, causing damages in Ponta Delgada (San Miguel) Cala del Heroismo and Playa de Vitória (Terceira) and Madeira. The mega-seism, with an estimated magnitude of 8,7 to 9,0, reached an intensity of X (Mercally) in the Algarve region. The total number of fatalities is estimated between the 20 000 and 40 000. Only in Lisbon, 20 000 of the 200 000 could have been killed. Of the 20 000 existing buildings, only 3 000 could be occupied after the event. Huge damage or collapse was found in 32 churches, 60 chapels, 31 monasteries, 15 convents and 53 palaces. Despite the quick response to the catastrophe, the reconstruccion of the city of Lisbon took more than a hundred years.

— January 13, 1804. This earthquake had a magnitude of 6,7, and epicentre in the Mar de Alborán. It was followed by several aftershocks that struck the city of Motril.

— March 21, 1829. With a magnitude of 6,6 and epicentre in Benejúzar, Rojales and Torrevieja, this seism caused 389 fatalities, 377 wounded, the collapse of 2 965 residential buildings and severe damages of 2 396 of them and the collapse of the bridges over the Segura river in Almoradí, Benejúzar, Dolores and Guardamar. Its effects reached to the populations of Almoradí, Algorfa, Rafal, Torrelamata, Daya Vieja, Guardamar, Dolores, Redován, San Fulgencio and San Miguel de Salinas. Half of those killed were in Almoradí, a village with narrow streets and tall buildings that collapsed on each other. The period between 1820 and 1830 was the most seismically intense in the south of the province of Alicante, due to the activity of the seismotectonic lines of Bajo Segura, including the faults of Benejúzar-Benijófar, Guardamar del Segura and Torrevieja. In general, the coast of Alicante is sunk about 10 meters below the Torrevieja fault.
— November 11, 1858. Originated at the underwater valley of Sado, it was one of the main earthquakes that affected Portugal. It reached an intensity of X in Setúbal, causing great destruction in several towns.
— December 25, 1884. With a magnitude of 6,5 and epicentre at Arenas del Rey, this earthquake caused the total devastation of several towns in the province of Granada, leaving 839 dead, 13 000 injured and 4 400 buildings destroyed.
— April 23, 1909. With epicentre in the Benavente area (fault of the lower Tagus valley) this seism had a duration of approximately 20 seconds. Of magnitude 6,0, the maximum intensity was experienced in Benavente (IX) and Lisbon (VII), the eastern part of this city being the most damaged, with fallen chimneys and cracks in facades and walls.
— February 21, 1964. A seismic crisis shook the western part of the island of S. Jorge (Azores), with a magnitude of 5,5, registering maximum intensities of VIII / IX in the Rosais. It was associated with an underwater eruption near the Rosais. Pico reached the maximum intensity of VI in the Piedade area, and in Faial there were maximum intensities of V in Horta, Ribeirinha and Cedros.
— February 28, 1969. An earthquake of magnitude 7,9, with epicentre in the abyssal plain of Ferradura, was felt in large part of the peninsula, reaching a maximum intensity of VIII in the west of Windward, with significant damage to some old masonry constructions. In Lisbon, hundreds of chimneys were damaged, including collapses. There was slight to moderate damage in several churches and chapels in the south

of Lisbon. In Huelva, 4 people perished and 18 houses were declared uninhabitable.

— November 23, 1973. The earthquakes took place on the 23rd of November and 11th of December of 1973. With magnitudes of 5,8 anf 5,6 respectively, they were felt in the islands of Pico and Faial. They caused 61 deaths and severe damages, including partially collapsed buildings and blocked roads.

— January 1, 1980. This earthquake affected the islands of Terceira, S. Jorge and Graciosa (M 7,2), and caused great damage in the city of Angra do Heroísmo, mainly in one or two-story buildings in traditional stone masonry, damaging 15 000 homes (50% of the existing ones) of which 5 000 collapsed. The earthquake also generated a small tsunami. The earthquake caused 61 deaths, many of them due to landslides on the island of S. Jorge. The reconstruction of the destroyed areas was the largest operation carried out in Portugal in the last 100 years.

— July 9, 1998. This swarm of earthquakes began on July 9, 1998, with an epicenter about 15 km NE of Horta and magnitude 5,9. About 10 600 aftershocks were recorded and lasted approximately 4 months. The earthquake caused 8 deaths, 100 injuries and 2 500 displaced people, affecting around 35% of the buildings in Faial and 10% in Pico.

— February 12, 2007. With a magnitude of 6,1, this was the strongest quake felt in Spain after 1969. The epicentre was located at 200 km from the Portuguese cape of S. Vicent. The shaking was felt in most of the peninsula, and caused the dislodge of many buildings. On August 12th 2007, a second earthquake of 5,1 with epicentre in Ciudad Real was recorded. Is was again felt in most of the peninsula, and, although no personal damage was caused, the conference hall of the Municipal Theater of Almagro, a 19th-century building, was destroyed.

— December 17, 2009. This earthquake, with a magnitude of 6,3 in the Richter scale, affected the region of Andalucía. It caused chaos and panic among the population, afraid of the possibility of an associated tsunami, which luckily did not take place. The quake caused relevant damages in many residential buildings.

— May 11, 2011. This earthquake shacked mainly the locality of Lorca, in the region of Murcia. Its epicentre was located in the Alhama fault, and it had a magnitude of 5,1. It was preceded by a premonitory earthquake of 4,5 a few hours earlier on the same day. The shake was also felt in the provinces of Almería, Albacete, Granada, Jaén, Málaga, Alicante, Ciudad Real and some areas of the city of Madrid, where, due to the soil type, the ground accelerations got amplified. Multiple aftershocks occurred after the main earthquake. The Region of Murcia, in which Lorca is located, is the most active seismological zone in Spain, although this locality, specifically, is not among the most dangerous within it.

— January 25, 2016. Also known as the Alhucemas earthquake, of magnitude 6,3 and epicentre in the Alboran Sea, 77 km northwest of the autonomous city of Melilla, this earthquake was perceived with greater intensity in the northern area of Morocco (in addition to Alhucemas, particularly in the towns of Tirhanimine and Imzouren that are respectively 64 and 69 km from the epicentre) and in the autonomous city of Melilla. To a lesser extent, it was also felt in Gibraltar, along the coast of Almeria, Granada and Malaga. The tremor was also noticeable in more remote provinces, such as Cordoba and Seville. In total, the emergency telephone number 112 received in Spain more than 600 calls in which incidents were reported and advice of various kinds was requested.

5.2. EARTHQUAKE AND TSUNAMI OF 1755

The earthquake of 1755 is considered as the largest earthquake recorded up to this date. It was felt strongly in Lisbon, the Algarve, southern Spain and Morocco. Although causing no damages, it was also felt in most of Europe, the Azores and Madeira. The tsunami hit North Africa, northern Europe, affected the Azores and Madeira and reached as far away as Antigua, Martinique and Barbados.

A strong earthquake, with epicentre at sea in the Gorringe area, took place on a Saturday morning, November 1st, 1755, All Saints Day, around 9:40 a.m. Shortly after the earthquake, a fire started, mainly caused by stoves and candles fallen by the earthquake (Figure 18). The population tried to escape from the fire in the direction of the Tagus River. The waters of the Tagus initially descended, taking with them the ships moored at the dock. Around 11 a.m. the waters began to level up, climbed the walls of the pier and advanced through the Baixa 300 to 400 m (Terreiro do Paço and streets near the river banks). According to the captain of an English ship, the waters rose about 16 feet three times in a row for 15 minutes. Only at 7 a.m. on Sunday would the tide return to normal.

Figure 18. Artistic recreation of the Lisbon tsunami of 1755 (source: *Getty Images*).

The impact of the 1755 earthquake is described in many contemporary accounts, such as the following (included in the Lisbon Emergency Plan for Seismic Risk): "(…) Behold, suddenly, that the sea enters through the barrier with a strong August flood. (…) However, when it exceeded its old limits, it hit many buildings and flooded the neighbourhood of S. Paulo (…)" (Mendonça, 1758), "(…) and it flooded partially with its ebb and the edge of the waters flowed, leaving its former bed and flooding Alfândega, Terreiro and Vedoria (…)". According to Baptista *et al.* (1998), the Baixa da Cidade was flooded, with a penetration of 250 m, and the wall "Fernandina" (remade by King Felipe I) acted as a strong barrier to the passage of water. The area between the old Ribeira das Naus, Terreiro do Paço and Jardim do Tabaco was completely flooded. Another reference reports that "Bugio Castle was so covered in water that the garrison fired SOS shots and everyone was forced to retreat to the highest part of the tower".

According to contemporary reports, building damage began in the second phase of the earthquake, reaching its peak in the third. Some people had time to flee their homes between the first and second phases, but many of them were trapped by landslides. The movement of people was quite random. Shortly after the earthquake, there was a concentration in Largo de S. Paulo, where the tsunami wave arrived at 11:00 a.m., causing great losses (Oliveira, 2005).

The total number of victims of this earthquake is estimated in 20 000 to 40 000 people. In Lisbon alone, it is believed that, of the 200 000 inhabitants of the time, 20 000 would have died. Of the 20 000 existing buildings, only 3 000 could be reoccupied after the earthquake. 32 churches, 60 chapels, 31 monasteries, 15 convents and 53 palaces were totally destroyed or severely damaged. The reports of the time are not very consistent, which makes it difficult to calculate the exact number of victims due to the earthquake, tsunami and fire. The damage caused by the fire, which lasted approximately 6 days, was greater than that caused by the earthquake and the tsunami themselves (Santos, 2008). The complete reconstruction of the city of Lisbon took more than 100 years.

At the end of this chapter, teachers could propose the following activities to their pupils:

Suggested activities	
Simulate a tsunami	Page 57

SUMARY

Chapter 6. Why does my house shake?

The earth is constantly moving, and that is why small earthquakes are happening all the time. We do not feel them and they do not cause any damage. Only special measuring devices (sismographs) can capture such small movements. However, a stronger earthquake would be felt, and could bring down trees and buildings.

Still, earthquakes do not cause any problems by themselves. Imagine an earthquake taking place in the middle of the desert: what could happen? Nothing. What causes victims and damages are our buildings, if they are not properly prepared to resist earthquakes. We cannot predict when the earth will move, but we can reduce the effects and damage a shaking can cause if we know what to do at home, at school or on the street, before and during an earthquake.

When an earthquake occurs, its waves propagate through the ground in all directions. Buildings are generally design to withstand vertical forces due to their weight and gravity. This does not automatically mean that they can withstand the horizontal forces transmitted by earthquakes. These horizontal loads make walls, floors, pillars, beams and the connections between them vibrate and move (Figure 19). The difference in displacement between different parts of the structure results in very high stresses in its members, causing damage and even collapse.

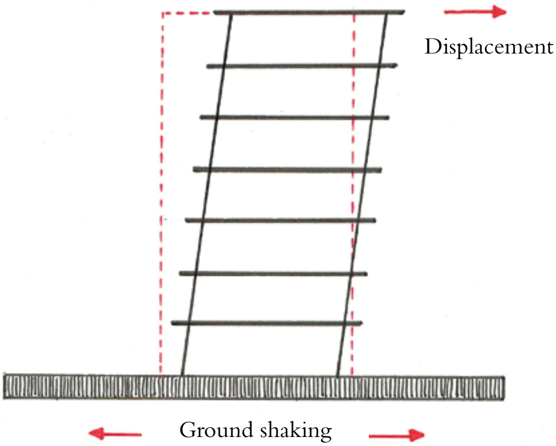


Figure 19. Building behaviour under an earthquake. If the building undergoes a large displacement, the structural elements such as beams, columns and walls could become damaged, making the building not safe (Emilio Romero Sánchez).

6.1. HOW DO BUILDINGS WITHSTAND EARTHQUAKES?

Several factors affect the seismic behaviour of buildings, such as their year of construction, materials, foundation type, symmetry, number of floors, etc.

Buildings can be designed in order to, with a given level of probability: endure an earthquake protecting their occupants, being used directly after the shake, or even keep on being operative during the event (like hospitals, for example).

It is important to underline that, as we learn more about earthquakes and building dynamics, buildings that once were regarded to as safe, could be reconsidered as un-safe under the light of new knowledge.

Some schemes employed to help the buildings endure earthquakes are related to the creation of a lateral load path, able to redistribute the seismic forces among the building structural elements. Braces are an example of such scheme (see Figure 20). These techniques are also employed in the rehabilitation of existing buildings, in order to reduce their vulnerability. In this case they are known as structural retrofitting.

We can also reduce the damages caused in a building under seismic action by limiting its deformations which, as has been explained before, can result in large stresses in the structural elements. Base isolation is an example of this scheme: the building is constructed on top of elastomeric bearings which isolate the structure from the ground. When the earthquake takes place, all the deformation concentrates in these elastomeric bearings, while the rest of the building behaves as a rigid body and moving as a single block. Buildings with base isolation are more prone to withstand a strong earthquake with little damage, and to can be occupied directly after the event (Figure 21).

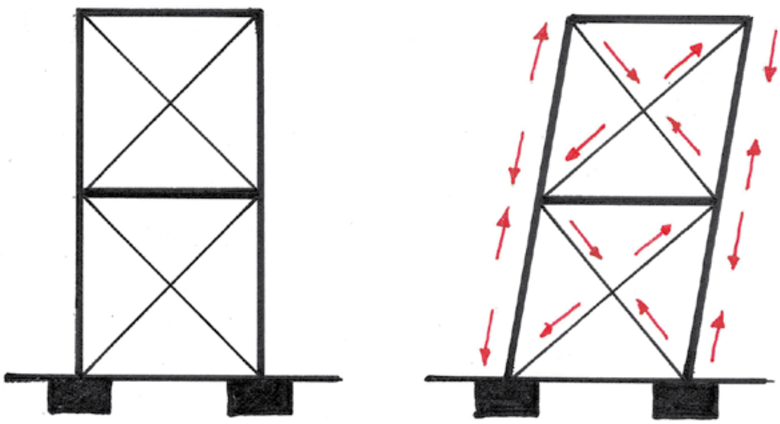


Figure 20. Use of braces for the creation of a lateral load path (Emilio Romero Sánchez).

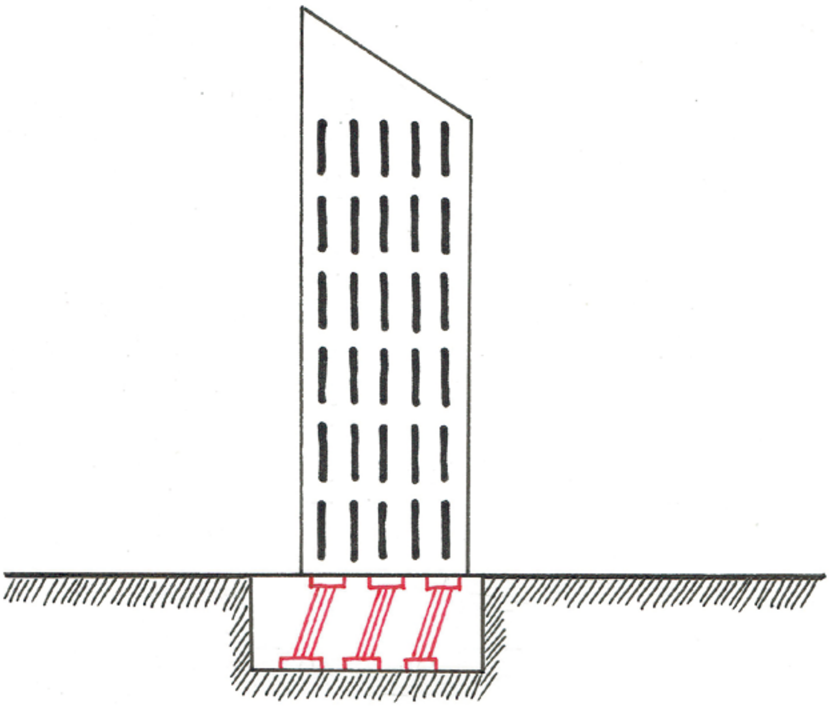


Figure 21. Base isolation (Emilio Romero Sánchez).

At the end of this chapter, teachers could propose the following activities to their pupils:

Suggested activities	
The Treme-Treme house	Page 58

SUMARY

6.2. THE RELEVANCE OF NON-STRUCTURAL ELEMENTS

The **structural elements** of a building constitute its structure, the scheleton: columns, beams, foundations, floors, etc. Without them, the building would not be able to stand up (Table 1). In case of an earthquake, the quality of construction of these elements is crucial to avoid collapse.

The **non-structural elements** are parts of a building which are not strictly needed for it to stand up, like ceilings and non-load-bearing partition walls, or free standing, like furniture and equipment (Table 1).

Table 1. Structural *vs*. Non-structural elements

Structural elements	Non-structural elements
Colums	Roof covering
Beams	Partition walls
Load bearing walls	Façades
Foundations	Ceiling
Floors	Chimney (<6 m)
Stairs	Furniture
Roof system	Artworks
Chimney (>6 m)	Installations
	Computers
	Windows
	Lifts

During the shaking, if they are not properly fixed to the wall, furniture like cupboards and libraries and the objects stored in them, can fall. Hanging elements, such as ceilings or lamps, also represent a danger. Doors and windows can deform, making it difficult to open them and exiting or entering the building. Electricity can fail and, consequently, the fire alarm system can stop working. Seismic hazard is also present outside the buildings: failure of as gas pipe, falling of street lamps, collapse of buildings, roads blocked by debris, and many others (Ferreira, 2012).

Looking at the bright side, non-structural elements are the easiest and cheapest to intervene, as we will see in the next chapter. Recent studies indicate that 60% to 70% of injuries and hospitalizations that occur during an earthquake are caused by non-structural elements.

6.3. HOW TO REDUCE NON-STRUCTURAL RISK?

The measures of protection against non-structural damage are, mainly, low cost (or even free!) and easy to apply and, most important of all, they have a great impact: lives can be saved and wounds and material losses can be prevented.

Small gestures can be very relevant. MOVE, PROTECT, SECURE and RETROFIT (Figure 22), are measures that everybody can take in order to avoid the damages caused by non-structural elements, so that they cannot hurt someone, damage something or block an escape path by falling or sliding.

The campaign MOVE, PROTECT, SECURE and RETROFIT was developed within the proyect KnowRISK (2017). This proyect's main objective was to raise awareness among to population about the seismic non-structural risk and how it can be reduced. Several risk awareness and communication materials have been developed, some of which are mentioned and used in this educational guide.

— MOVE heavy objects from the top shelves to the lower ones. MOVE the beds, putting them far from the windows in order to avoid the broken glasses to fall over them.
— PROTECT the most fragile and/or valuable things. For example, you can use double side tape to avoid objects to slide and overturn. Use curtains to avoid the broken window glasses to cause damages or cuts.
— SECURE large non-structural elements to the walls, like libraries, cupboards, bunk beds. SECURE fans, frames, mirrors, computers, electric equipment and suspended lamps as well.
— RETROFIT the non-structural elements to avoid causing serious damage or interrupting the functionality of the building. Verify that the gas and water pipes and conducts are fixed and can withstand horizontal action; check whether the balconies or parapets show signs of degradation; opt for laminated or tempered glass on windows with large spans; reinforce the chimneys, etc.

The solutions presented in Figure 22 avoid or reduce material losses, an important factor when talking about shops or warehouses. They can also help relevant buildings, such as hospitals, schools or emergency centers, to keep their functionality after an earthquake.

SUMARY

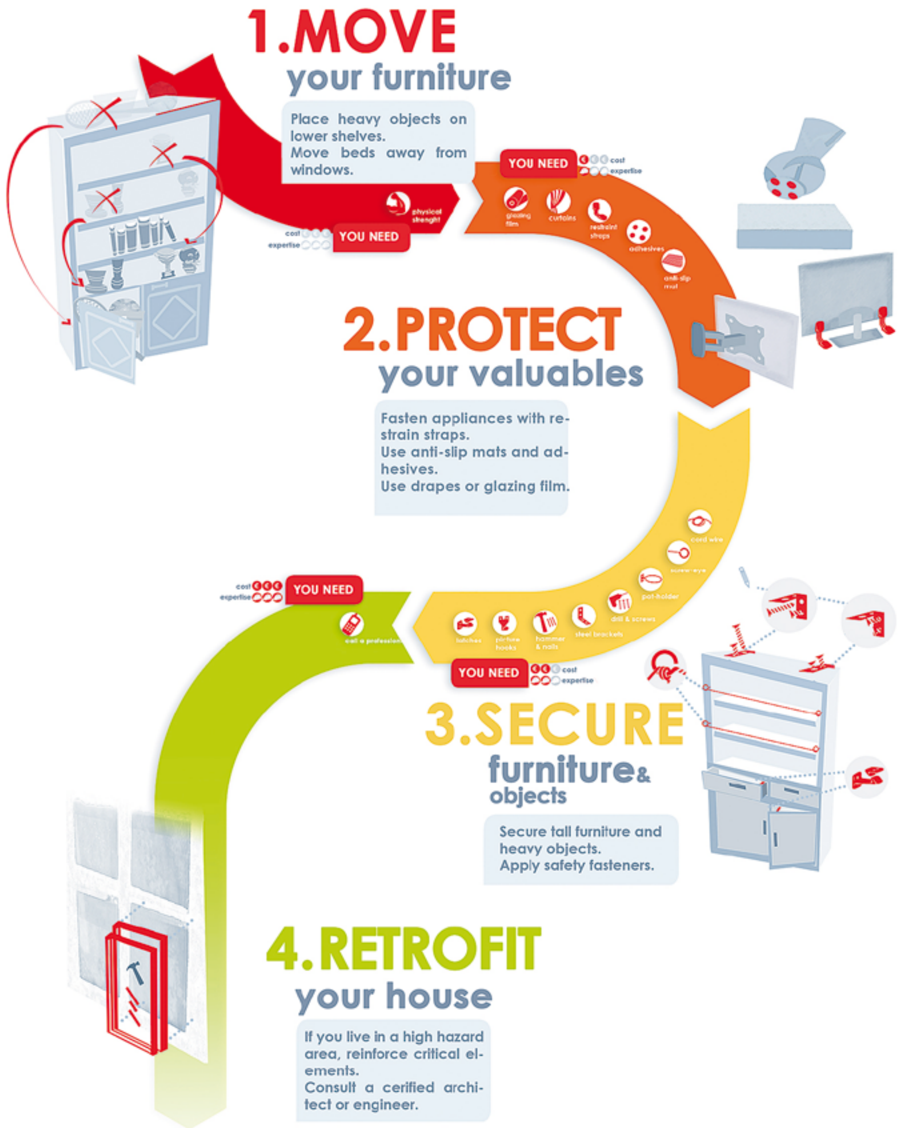


Figure 22. Non-structural protection measures that can be adopted at school, at work or at home: move, protect, secure and retrofit. For more information, see the Practical Guide to KnowRISK, <https://knowriskproject.com/>.

At the end of this chapter, teachers could propose the following activities to their pupils:

Suggested activities	
Hunting for non-structural risk	Page 63
Model: Move, protect and secure	Page 65
Spot the differences	Page 67
Treme-Treme computer game	Page 69
Treme-Treme cootie	Page 70
KnowRISK board game	Page 73

SUMARY

Chapter 7. What to do in the case of an earthquake or tsunami?

7.1. IF I AM AT SCHOOL AND AN EARTHQUAKE BEGINS, WHERE MUST I GO?

Don't leave the classroom until the tremor finishes. Keep away from windows, cupboards and lamps so nothing falls on you. You must stay under the desk and not use either the staircases or the lift. It is fundamental to keep calm and behave as you learnt in the drills when the earthquake finishes.

7.2. WHICH ARE THE MOST DANGEROUS PLACES INSIDE A BUILDING?

Close to cupboards, wardrobes or shelving that aren't fixed to the wall, or whose doors don't stay shut (for example, the doors of the kitchen cupboards). Avoid staying close to windows too, as their glasses can break and hurt, or to mirrors, pictures or other objects which could fall.

7.3. IF I AM OUTSIDE AND FEEL AN EARTHQUAKE, WHAT MUST I DO?

Look for an open space, without trees, buildings, electricity posts or other elements which can fall on you. Stay away from buildings and the façades, as roof tiles, chimneys or decorative elements may fall on you. If you are near the coast, you could be in danger of tsunamis, so keep away from the sea. Go to high ground.

SUMARY

7.4. WHAT MUST I DO AFTER AN EARTHQUAKE?

After the earthquake has finished, turn off the electricity and the gas. Go outside calmly, seek an open space away from buildings, trees and electricity poles. If you are close to the sea, go to a high place away from the coast.

7.5. IN CASE OF TSUNAMI, WHAT MUST I DO?

After an earthquake and if you are in the house, at school or at work, bear in mind that in coastal zones (high-risk) you have few minutes to act (5 to 10 minutes), that's to say, to start the evacuation (Figure 23). Once the earthquake has finished, evacuate the quickest possible on foot. Always follow the indications of the evacuation plan (horizontal and vertical). Some beaches have evacuation signs in the case of a tsunami (Figure 24) and sirens.

Figure 23. Risk of tsunami (source: <www.tsunamizone.org>).

Figure 24. What to do in coastal zones after an earthquake?
(source: <www.tsunamizone.org>).

At the end of this chapter, teachers could propose the following activities to their pupils:

Suggested activities	
Locate tsunamis around the world	Page 56
Simulate a tsunami	Page 57

SUMARY

Chapter 8. Activities

8.1. PUZZLE OF TECTONIC PLATES

In this activity the students will assemble a puzzle/map showing the countries, the continents and the tectonic plates. The image can be printed and pasted onto cardboard, in order to create a large puzzle that allows to carry out the activity in groups. Alternatively, it can be printed in a smaller format, for individual use. The map is an excellent work tool because, allowing to visualize the location of the tectonic plates in relation to the oceans and the continents.

Materials:

— Cutout world map.
— LEGO or wood blocks.

Discussion:

At the end of the activity the students will be able to:

— demonstrate how the tectonic plates which cover the Earth fit as pieces in a puzzle;
— locate Spain, Portugal and other countries in their puzzle;
— note that Japan and California are located at the limit of the same tectonic plate (Pacific plate), in a zone of convergence called the Pacific Ring of Fire;
— note that Australia, as it is located in the middle of a plate and far from the limits, does not suffer from earthquakes;

SUMARY

Figure 25. Primary school students putting the puzzle together individually (Patrícia Gramaxo).

Figure 26. The same activity developed in groups (Beatriz Zapico Blanco).

— give a simple explanation of the relation between the tectonic plates and the distribution of the earthquakes in the world, for example in the Iberian Peninsula;
— give a simple explanation about the formation of volcanos in the archipelagos of the Azores and the Canary Islands, among others;
— if they place a small LEGO or wood construction on the puzzle and knock under the table, the students will understand that the interior of the Earth moves what is above its surface.

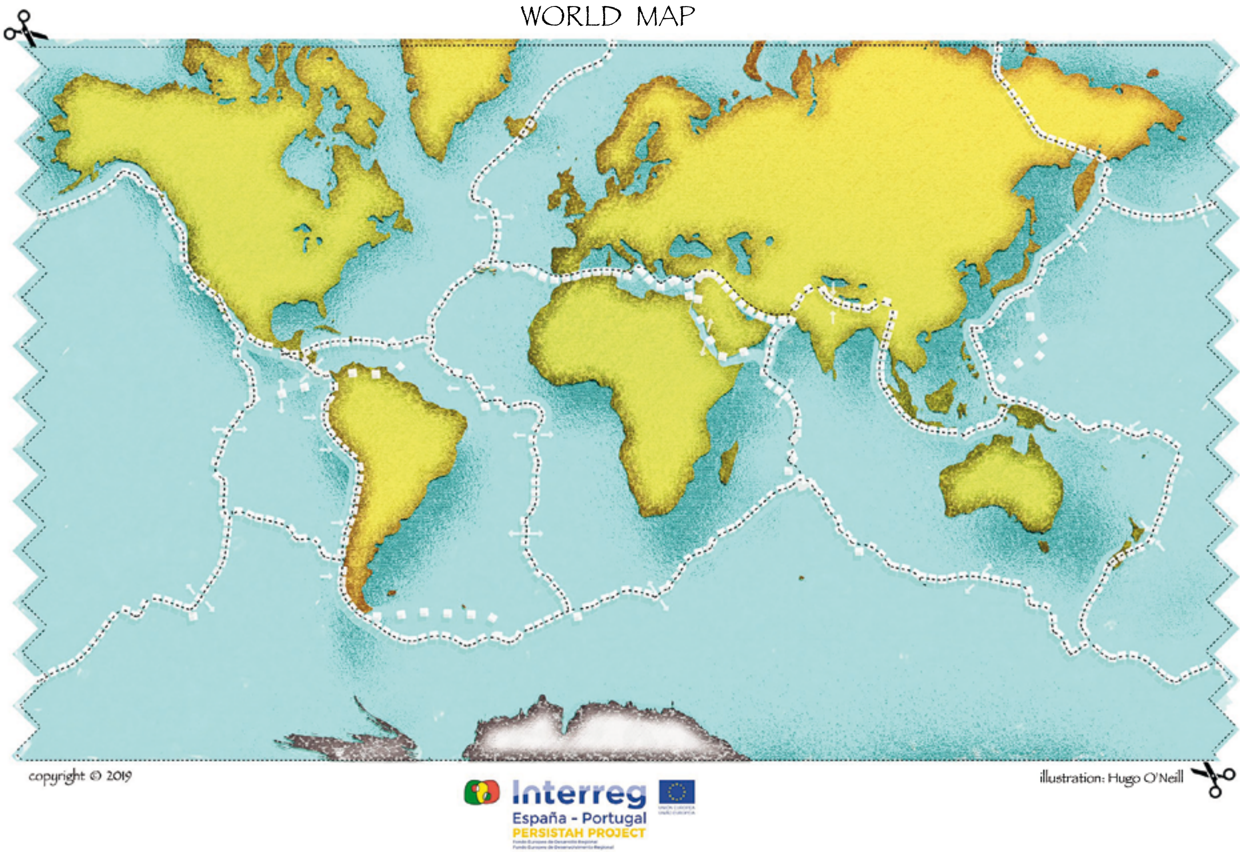


Figure 27. Puzzle/world map (to be printed and cut).

8.2. TROUBLES ALWAYS COME IN THRESS

To find out the seismicity of our country, it is essential to identify the zones at greatest risk. This activity proposes combining hazard with creativity, manual skills, the coordination of colours, etc. (see section 5: "Are we in danger here?"). Other risks are associated with earthquakes can be discussed, such as tidal waves, landslides or fires, and things to do in order to be safer against them could be proposed.

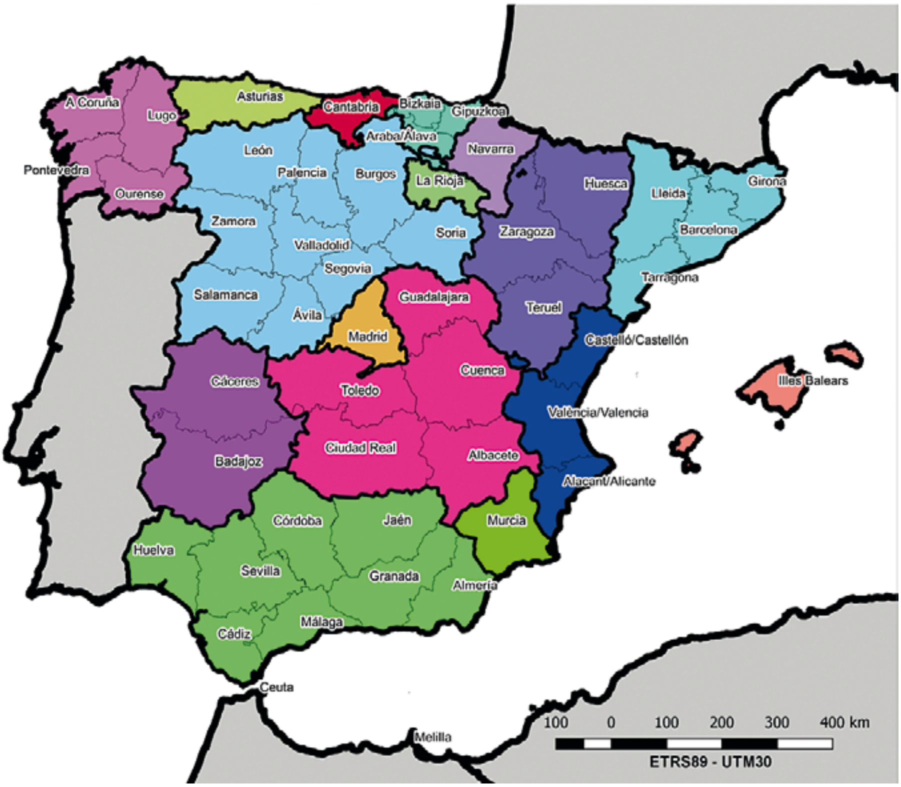


Figure 28. Spanish regions (adapted from <www.ign.es>).

Materials:

— Map of the Iberian Peninsula.

SUMARY

Procedure:

— Locate in the map the region where you live.
— Paint the regions according to the seismic risk: red (high-risk), orange (moderate), yellow (low) and green (very low).
— In what seismic and tsunami risk zone is the region where you live?

___High ___Moderate ___Low ___Very low

8.3. LOCATE EARTHQUAKES AROUND THE WORLD

More than a million earthquakes occur every year on Earth! Most are of a very low magnitude, so low that we don't even feel them. In Spain there are around 12 main earthquakes of a magnitude over 3,0 per year. It is important to find out exactly where an earthquake takes place. This information can help seismologists to identify and map the danger, as well as helping scientists to understand the location and the movement of the tectonic plaques.

Figure 29. Examples of the activity development (Hugo O'Neill).

Materials:

- Map of Spain, Portugal or the world.
- Computer and internet connection.
- Coloured stickers or pins (it is important to have at least three different colours but there can be more).

Procedure:

Assign a magnitude range to each colour. We can take advantage of an earthquake in any place in the world to reflect and carry out critical thinking in the classroom. You can visit the site *European-Mediterranean Seismological Centre* (EMSC, <https://www.emsc-csem.org>).

Investigate where earthquakes have occurred today and ask the students to place red circles to identify the earthquakes of greater magnitude, yellow circles for those of moderate magnitude and green for those of less magnitude. Do this activity weekly, for example, and in the course of three months, and you will observe how the limits of the tectonic plates are drawn. This is a good way for the students to discover where earthquakes can happen.

Discussion:

- Discover patterns of earthquakes all over the world.
- How many earthquakes happened today?
- Identify in the map where the earthquakes of greater magnitude happened today.
- Why do earthquakes happen more in some places than in others?
- What have earthquakes to do with the tectonic plaques?

8.4. LOCATE TSUNAMIS AROUND THE WORLD

Figure 30. Earth globe (Hugo O'Neill).

Materials:

— World globe or cutout world map.

Procedure:

In this activity, students will pin on the map the locations of the most destructive tsunamis in history, and how far they reached:

— 1755 Portugal tsunami (origin: SW of Cape San Vicente).
— 1864 Alaska tsunami.
— 2004 Indonesia tsunami.
— 2011 Japan tsunami.

Discussion:

How are tsunamis related to tectonic plates?

SUMARY

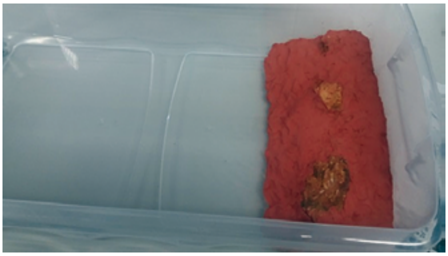
8.5. SIMULATE A TSUNAMI

In this activity the students are going to simulate a tsunami and will note its effect on buildings (note: this activity was created by the *Serviço Municipal de Proteção Civil de Portimão*, SMPC Portimão).

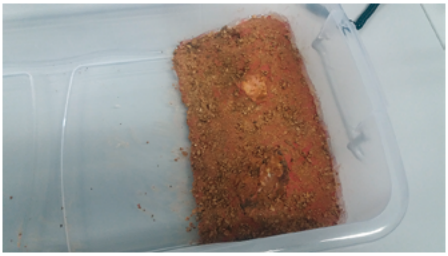
Materials:

— plastic box;
— clay;
— glue;
— sand and shells;
— varnish and brush;
— miniatures (houses, cars, trees, fish, etc.).

Procedure:



Fill one end of the box with clay and some rocks.



Paste it with glue and varnish.

Place the miniatures in the water and on the earth.

Tip one end of the box so that the water moves backwards. Put it horizontal observe the effect of the tsunami on the buildings!

Photo: *Serviço Municipal de Proteção Civil de Portimão,* SMPC Portimao.

8.6. THE TREME-TREME HOUSE

Thousands of people live in places all over the world where earthquakes are common. Most of the destruction caused by earthquakes is the result of the collapse of structures such as houses, hospitals, bridges, etc. This is why seismic engineering is so important. Architects and engineers save lives by designing buildings and structures which can withstand strong vibrations.

Materials:

- an A4 sheet of paper;
- spaghetti;
- marshmallows/rubbers.

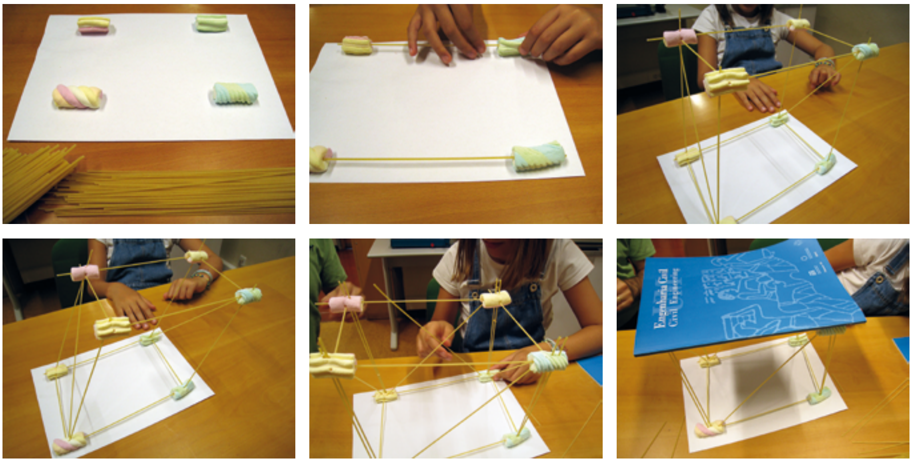


Figure 31. Example of the activity using spaghetti and marshmallows (Mónica Amaral Ferreira).

Or:

- an A4 cardboard base;
- 20-30 straws (approx. 14 cm);
- modelling clay.

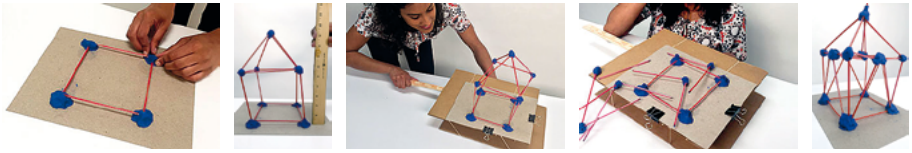


Figure 32. Example of the activity using straws and day (<https://pbskids.org/designsquad/build/seismic-shake-up/>).

Procedure:

Make a structure about 20 cm high, stable and resistant enough to withstand the vibrations of an earthquake. Put this structure to the test, shaking the paper as if there was an earthquake.

Or:

Cut out a "shaking house" (with the thickest paper possible or paste it on card-board after cutting it out) and do the earthquake test!

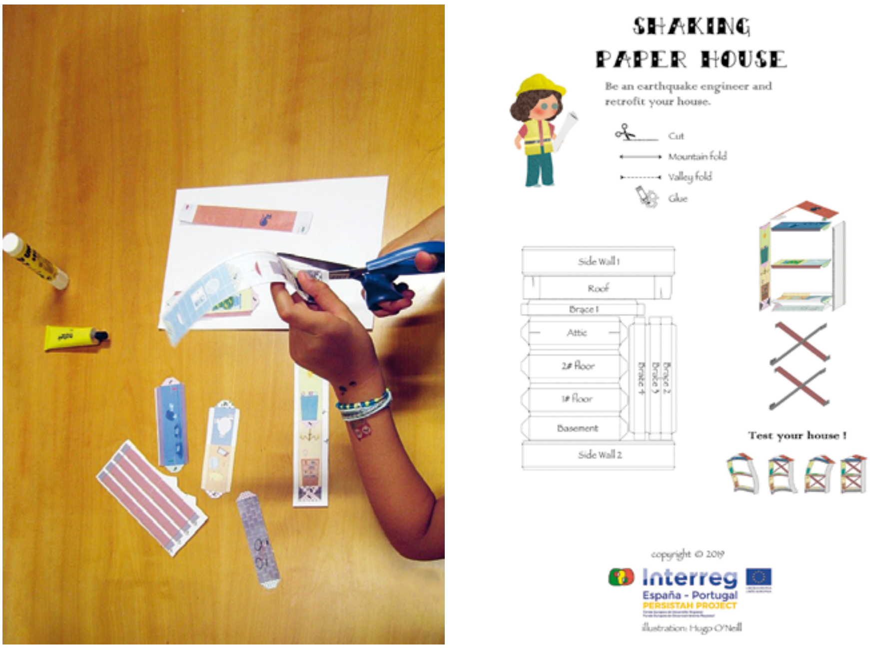


Figure 33. Building the Shaking Paper House (Photo: Mónica Amaral Ferreira).

Discussion:

How did your structure behave during the earthquake? If it wobble, toppled or collapsed, it's time to create a new design. Try to make your structure the strongest and most stable possible.

Did it go well? Go on to the next level and build an even higher structure!

What if…

… your structure has staggered? Transform the squares into triangles, adding diagonals for a greater stability.

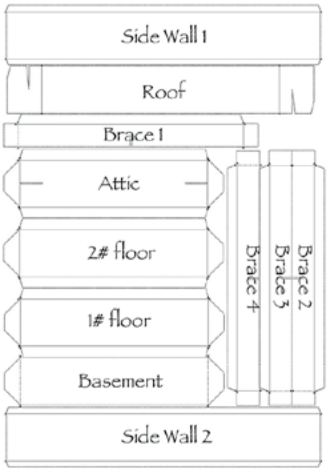
… your structure has tipped over? Perhaps your base is too small: make a larger and more resistant base.

… your construction has collapsed? Add triangles. Triangles are stronger than squares or rectangles made with the same material, due to their high geometric stiffness: a triangle is the only polygon which does not deform.

SHAKING PAPER HOUSE

Be an earthquake engineer and retrofit your house.

- Cut
- Mountain fold
- Valley fold
- Glue



Test your house !

Interreg España - Portugal
PERSISTAH PROJECT
Fondo Europeo de Desarrollo Regional
Fundo Europeu de Desenvolvimento Regional
UNIÓN EUROPEA
UNIÃO EUROPEIA

illustration: Hugo O'Neill

SUMARY

SUMARY

8.7. HUNTING FOR NON-STRUCTURAL RISKS

You are going to do, with the help of your family, a visual inspection card of the potential hazards existing in your house (living room, dining room, kitchen, bedrooms) that may cause damage or injury during an earthquake. Architects and engineers often carry out this task to check the safety of structures and make plans to prevent damage in case of an earthquake.

You can make a film, a presentation, an interview or a drawing with what you have identified. Also, indicate some solutions to make your house safer in the case of an earthquake.

You can use this work to present your observations and suggestions to the person in charge of the school to help improving the safety in the classroom and in the school.

Materials:

— Evaluation sheet.

Discussion:

— Ask students what they know about non-structural elements and non-structural risk.
— Identify the safest areas of the house.
— Where can protection measures be applied?
— Which solutions can be applied to reduce non-structural risk?

SUMARY

EVALUATION SHEET

Evaluator:_______________________________ Date:__________

Identify the room: living room ❑ dining room ❑ kitchen ❑ bedroom ❑ bathroom ❑ other ❑

Identify:

Ceilings and external elements	Are there any?	
	Yes	No
Suspended ceilings		
Air conditioners / ceiling heaters		
Suspended objects (lamps, vases, plants…)		
Decorative ceiling moldings		
Pipes / conducts		
Roof tiles (exterior)		
Balconies		
Chimneys		

Furniture and equipment	Are there any?		Are they well secured?
	Yes	No	
Cupboards, wardrobes			
Filing cabinets			
Shels			
Picture on the walls, wall lamps			
Decorative elements fixed on the wall, such as statues, sculptures			
Televisions, projectors, microphones, speakers			
Computers, printers, photocopiers			
Fire extinguishers			
Game consoles			
Furnitures / equipment on wheels			
Art pieces / plant pots in high places			
Aquariums			
Glass windows / doors			
Ventilators			
Kitchen equipment (stoves, oven, fridge, washing machine, dishwasher)			
Doors of wardrobes or cupboards with security locks			

8.8. MODEL: MOVE, PROTECT AND SECURE

In teams, students will build a small model to simulate an indoor environment (bedroom, living room, kitchen, classroom, etc.) which they will later "shake up" to show how the non-structural elements will be affected (objects, decorative items, glass, furniture, etc.).

First, place the furniture and the decorations. Then, identify the non-structural risks and finally apply protection measures (by using glue, changing the arrangement of the furniture, adding blinds or curtains, etc.).

Materials:

- 1 shoebox with no lid;
- leftover foam from a mattress or pillow;
- small boxes (turn them over and paint them) to make furniture;
- small round mirrors of different sizes;
- small Lego pieces or doll-house furniture can also be used, if available.

Figure 34. Examples of the activity using doll house (Beatriz Zapico Blanco).

The activity can also be carried out in groups using other materials such as KLine, MDF, etc.

Figure 35. Constructing the models with the kids (Photos: Nuno Patrício, RTP. Marta Vicente, Delta S. Silva [KnowRISK project, 2017]).

Discussion:

— Identify the main non-structural risks.
— Identify the corresponding protection measures.
— Discuss the topic and apply it to other environments.

8.9. SPOT THE DIFFERENCES: REDUCE THE RISK IN YOUR SURROUNDINGS

This activity can be carried out in small groups, by printing or projecting images of the 'home' and 'school' environments so that the whole class can identify the differences.

In general, the discussion becomes more intense when children start to tell their own stories related to the topic or describe the state of their own bedroom.

Discussion:

In this activity, by spotting the differences between the images, the aims are to:

- identify the non-structural risks in the bedroom or classroom;
- provide solutions to reduce the risk;
- involve the whole class in the discussion of the topic.

Look at the pictures and ask: what risks can you identify in the classroom? Put a circle around them. How can these risks be reduced?

Figure 36. Spot the differences (Hugo O'Neill).

SUMARY

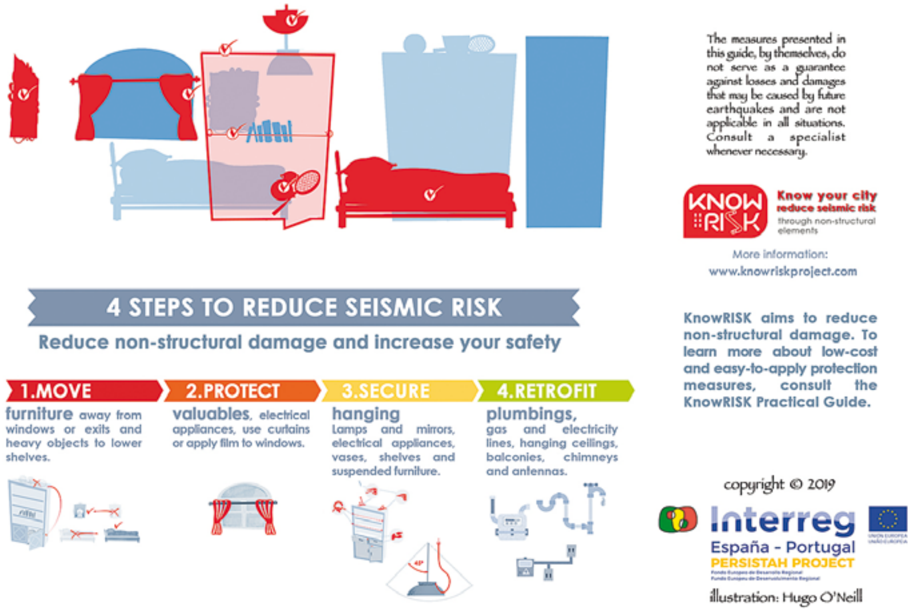


Figure 37. Steps to reduce the seismic risk.

8.10. TREME-TREME COMPUTER GAME

This educational video game make children aware of seismic risk in a playfully way. It transmits knowledge and encourages new generations to become aware of and prepared for earthquakes.

The game, available in Portuguese, English, Italian, French and Spanish, is freely distributed online. The application is available for Windows, macOS and Android.

Visit <www.treme-treme.com> and install the game on your school or home computer.

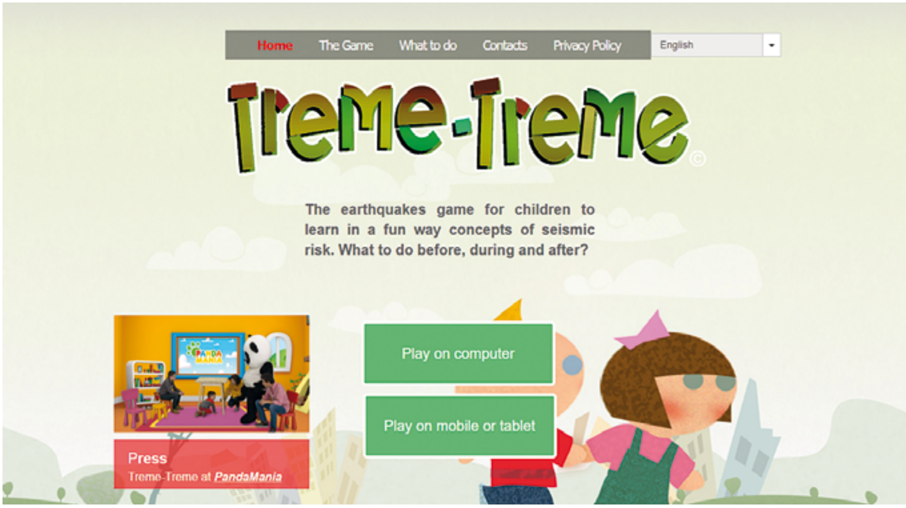


Figure 38. Treme-Treme computer game.

8.11. TREME-TREME COOTIE

This activity is related to the Treme-Treme game (<www.treme-treme.pt>) and its aim is to show some of the objects that must form part of an emergency kit. The children ask for a number, they say it aloud, they pick an object and then have to guess whether or not it belongs to an emergency kit. The answer is on the back of the question card.

Materials:

- "Treme-Treme" cootie (in the next page);
- scissors.

Discussion:

- Select which objects belong in an emergency kit.
- Explain why we must take some and reject others.
- Encourage the students to play the Treme-Treme game (<www.treme-treme.pt>) at school or at home, as all the items in the kit are used in the game.

SUMARY

Figure 39. Treme-Treme cootie.

8.12. WORD SEARCH

D	J	H	C	R	C	Y	B	G	T	C	D	F	Q	R
V	M	R	C	P	R	O	T	E	C	T	Q	V	I	Q
W	P	R	E	V	E	N	T	L	X	H	G	I	Q	C
S	I	Z	P	S	E	I	S	M	D	F	B	Z	U	B
J	D	A	I	Z	D	M	O	V	E	Q	P	W	C	M
H	S	M	L	B	L	O	B	I	I	C	J	S	D	Y
R	I	C	H	T	E	R	X	W	B	I	I	U	B	R
V	M	E	R	C	A	L	L	I	D	F	S	R	D	W
R	H	W	J	P	N	E	P	I	C	E	N	T	R	E
G	P	F	A	T	T	I	Y	C	W	A	B	Z	Q	O
Q	L	R	Q	M	K	D	W	G	C	A	C	R	K	R
F	D	E	F	D	X	Q	Z	E	P	F	I	X	V	N
E	A	R	T	H	Q	U	A	K	E	H	W	E	E	T
Z	V	N	M	A	G	N	I	T	U	D	E	W	W	N
D	A	H	P	G	K	M	V	T	S	U	N	A	M	I

Have fun searching the following words:

EPICENTRE
MERCALLI
PROTECT
EARTHQUAKE
SECURE
MOVE
RICHTER
TSUNAMI
MAGNITUDE
PREVENT
SEISM

8.13. KNOWRISK BOARD GAME

This board game is based on the Practical Guide of the KnowRISK project which shows the simple steps that are needed in order to make your home safer.

Figure 40. KnowRISK board game.

Visit KnowRISK, <https://knowriskproject.com/practical-guide-board-game>, print the game and cut out the cards.

Number of players: 2 teams (maximum 4 players in each team) + 1 referee.

Rules: each team chooses a job that represents them (fireman, public safety officer, geophysicist or an engineer).

Each player takes one card from the deck in each round and places it on one of the 4 trays (red, orange, yellow and green) according to the right action: move, protect, secure or retrofit. The teams can discuss about the choices. The referee can intervene by approving or rejecting their choices. If a card is rejected, it goes back to the deck and the player has to wait until their next turn.

The team that manages to place the most correct cards on the board wins.

SUMARY

Chapter 9. Leaflet | Earthquake safety at schools

The KnowRISK practical guide shows you how to prepare your home, classroom or workplace for an earthquake. Moving, protecting and securing are small gestures that can save lives, avoid material losses, and prevent the functional loss of a building. The practical guide can be downloaded here: <https://knowriskproject.com/practical-guide/>. Post this guide on your school bulletin board!

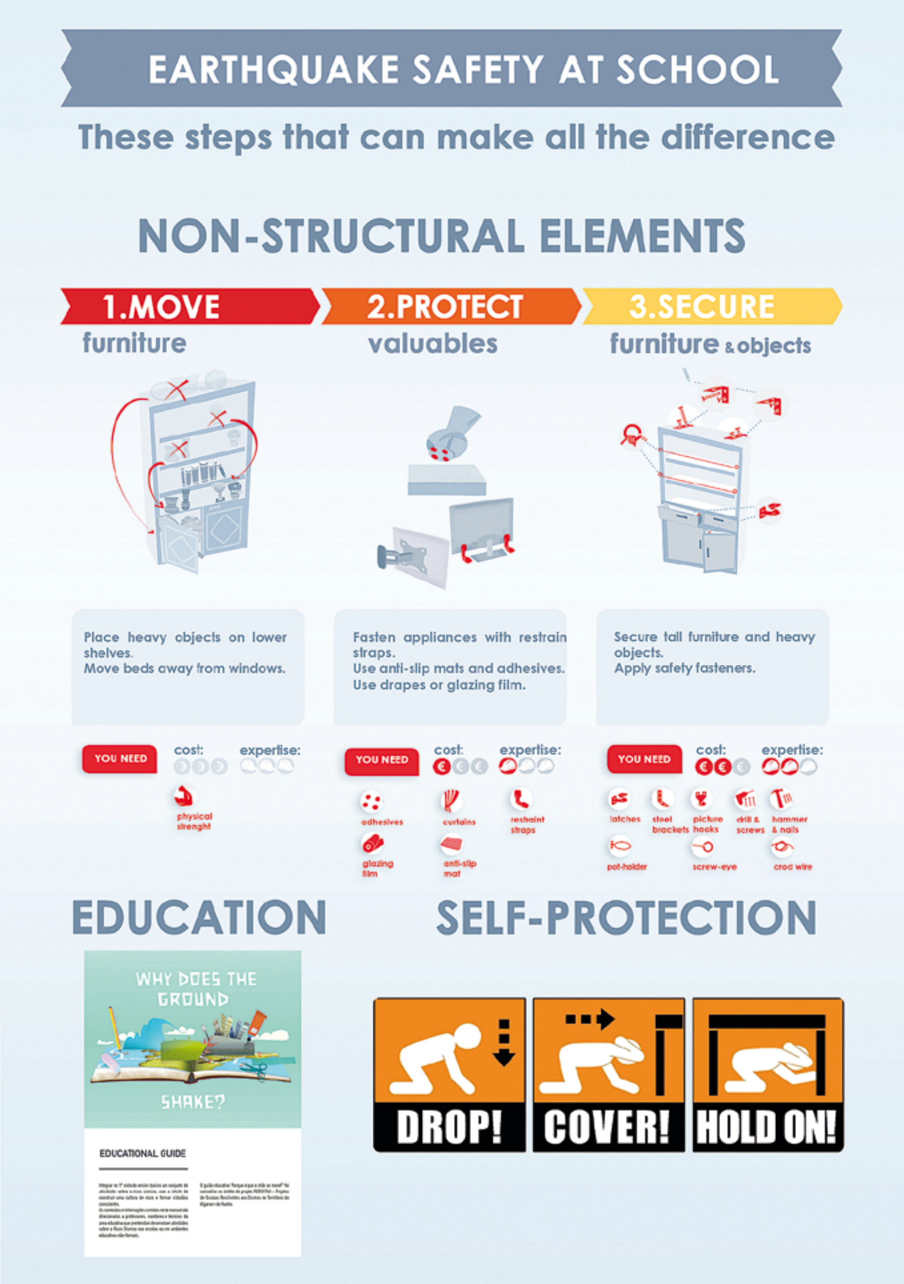


Figure 41. Seismic safety at school: non-structural elements (Hugo O'Neill).

SUMARY

Chapter 10. Case study

On June 17th 2019, the students of first year of CEB (6-7 years old) from the "*Jardim-Escola João de Deus – Estrela*" school, located in Lisbon, carried out an experimental activity in a classroom. By using the Educational Guide "Why does the ground shake?", the teacher prepared the material in order to develop an Experimental Protocol.

This Educational Guide allows teachers to create their own Experimental Protocol. Below, an example of its application is presented.

School: ______________________________

Lesson nº: ______________________________

Summary: ______________________________

EXPERIMENTAL ACTIVITY. WHY DO EARTHQUAKES OCCUR?

1. Introduction

We have heard news about earthquakes shaking our Planet. We have done exercises at school that have shown us how to act in these situations, such as staying under a table and counting to 60. The Earth is in constant motion and is not only due to the movements of rotation and translation.

2. Question - problem

Why do earthquakes occur?

SUMARY

3. Predictions

Indicate with a cross the options that you think will answer the question-problem. *Earthquakes occur…*

… due to the movements of the Earth around the Sun	
… because the Earth has a lot of water and the ground moves	
… because the surface of the Earth is formed by plates that move	

4. Material

a) Modelling the planet Earth in modelling clay.
b) Puzzle and construction pieces.
c) Chocolate bars that represent the Earth's crust.

5. Method

1. Observe the internal structure of the Earth through a model made of modelling clay.
2. Create the puzzle that represents the planet's surface and identify the pieces as the tectonic plates that constitute the earth's crust.
3. Make the two extremites of the chocolate bar collide with each other and observe what happens.
4. Join the ends of the chocolate bar and make them move in parallel in the opposite direction and observe what happens.
5. Move the two halves away from the chocolate bar and observe what happens.

6. Results

When we use chocolate bars, we observe that the extremities are modified according to the movements we perform. The same goes for the boundaries of tectonic plates.

SUMARY

Divergent plates	Convergent plates	Transforming plates
collide.	slide in parallel.	move away.

Join by a line.

7. Conclusions

Indicate with a cross (X) if the statements are true (V) or false (F).

a) Through this experience, we can conclude that:

	V	F
Earthquakes occur because the interior of the Earth is made of constantly moving materials		
Earthquakes occur because the tectonic plates do not move		
Tectonic plates move because the interior of the Earth is always in motion		

b) With this exercise, we learn that:

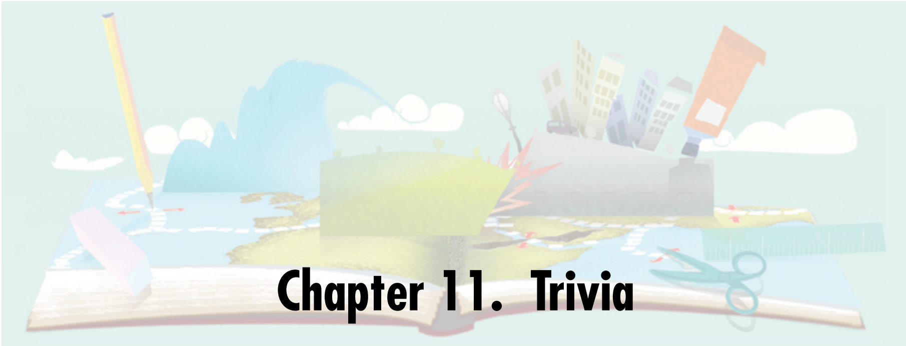
	V	F
Earthquake, shake and tremors are antonyms		
The interior of the Earth is formed by nucleus, mantle and crust		
The surface of the Earth looks like a puzzle of plates that fit together		
The crust is formed by several ergonomic plates		
Tectonic plates can collide, move away or slide in parallel		
We can use chocolate bars to represent the boundaries of tectonic plates, so we can carry out this activity alone		

SUMARY

Mónica Amaral Ferreira
Beatriz Zapico Blanco (coords.)

c) Correct the statements you indicated as false in the previous exercises.

SUMARY



Chapter 11. Trivia

- Did you know that an earthquake could be named as seism, earth tremor or quake? These words are synonyms.
- Each year, more than one million earthquakes occur on the Earth.
- Just to have an idea, the tectonic plates move around 8 centimetres per year. This is the speed at which a nail grows!
- The Euro-Asian plate moves away from the North-American plate at an average speed of 2,5 centimetres per year (this is 25 kilometres in a million years!).
- The largest mountain range in the world is underwater. The mid-Atlantic ridge (Figure 43) is the largest mountain range in the world, with about 15 000 km of length.
- The highest mountains in the world are still in formation! The Himalayan Mountains beging their formation about 60 million years ago, when the Indian plate collided with the Eurasian plate. Currently, both plates are still in convergence and the Himalayan Mountains are in constant transformation.
- In the Pacific Ocean, more than 80% of the earthquakes occur in the so-called "Ring of Fire". This is an area of high geological instability, whose shape is similar to a horseshoe. The ring spreads along this ocean, which is the largest in the world. This area is characterized by the presence of several tectonic plates, which leads to a high frequency of occurrence of earthquakes and tsunamis.
- Did you know that a tsunami could reach 800 km/h? This is the speed at which airplanes fly.

SUMARY

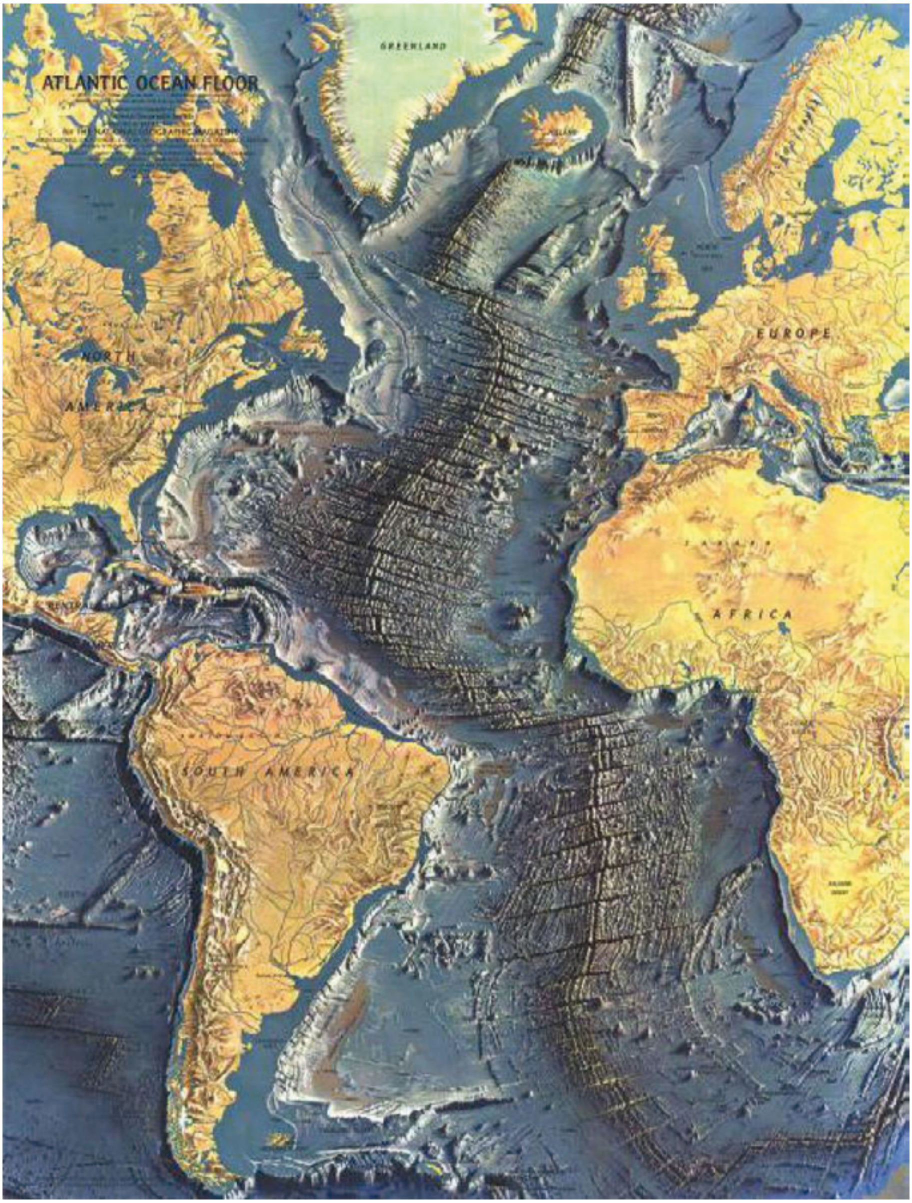
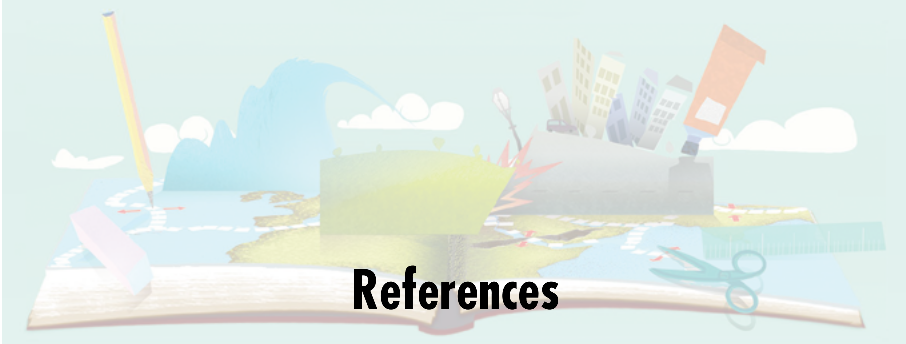


Figure 42. Mid-Atlantic ridge.



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SUMARY

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SUMARY

List of figures

SUMARY

The aim of this guide is to integrate a set of activities about seismic risk in the first cycle of basic education in order to enhance the awareness of the population regarding this risk.

The contents of this guide are intended for teachers. instructors and technical educative staff who would like to perform seismic risk related activities in schools or non-formal educational environments.

The educational project “Why does the ground shake?” was conceived in the frame of the project PERSISTAH- *Projectos de Escolas Resilientes aos Sismos no Território do Algarve e de Huelva.*

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