SCHOOLS STUDY EARTHQUAKES

Guides for Teachers

Pedagogical Framework
Implementation Guide
Seismology Handbook

Erasmus+

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Pedagogical Framework

1. Indroduction

The School Study Earthquakes (SSE) project aims to increase students' interest in scientific processes, influence their awareness of how earthquakes affect their life, as well as assisting them to develop key skills, such as analysis and problem solving skills through the study of seismology. Exploiting the innate curiosity of students about natural phenomena enables lifelong learning (National Research Council, 2000). In order to achieve this goal, teacher's role is significant. Inquiry – based learning (IBL) is an effective method that connects preexisting representations with the accepted scientific knowledge and promotes scientific literacy (Panasan & Nuangchalerm, 2010). Due to the continuous growth of research interest in the improvement of science education through IBL, competences are required from teachers in order to design science lessons (Alake-Tuenter, Biemans, Tobi & Mulder, 2013; Maaß & Doorman, 2013). Therefore, the Pedagogical Framework that is a requirement of Intellectual Output 1 (O1) of the present project will serve as a guide in assisting teachers in planning and implementing inquiry lessons and activities within their science classrooms. The framework is built around three components, which are as follows:

a) Project-mapping with the school curricula of the national educational systems of the participating countries
b) Determining the educational and pedagogical role of the teachers leading the students' teams involved
c) Further sound concepts and tools for the development of additional inquiry based learning scenarios in order to enhance the learning experience of students in the school teams participating

The Pedagogical Framework of the SSE project that is presented is flexible, widely applied and offers teachers the main structure for designing learning and evaluation processes for their students (Pedaste et.al, 2015).

2. Definition of inquiry – based learning

The National Research Council (1996) defines inquiry as the:
Diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (p.23)

As a construct of science and science education community, inquiry refers to methods that scientists employ, the pedagogical approach that teachers follow and the cognitive development of students (Minner, Levy & Century, 2010). Inquiry contains not only the engagement with scientific practices, but also the understanding of the process and dissemination of scientific knowledge (NRC, 2000). As a process, IBL occurs when there is curiosity and need to solve a problem that the learner notices and should model scientific approaches that resemble scientists inquiry habits (National Science Foundation, 2000).

Ideally, IBL aims in assisting students to gain, in a progressive fashion, inquiry competences (Bell, Smetana & Binns, 2005) necessary for daily life and for performing scientific investigations independently. This discovery process is divided into phases and sub – phases in order to guide students' scientific thinking more effectively and to ensure that they are engaged into authentic scientific processes. It should be noted that for the purpose of this project, the focus for developing this pedagogical framework relies both on learners' and teachers' role. An analytical description of the inquiry phases is provided in section 5.

3. Theoretical underpinnings of inquiry – based learning

IBL approach is built on the philosophy of constructivism, which considers that students and adults learn by active development and structuring of knowledge based on everyday life (Driver, Asoko, Leach, Mortimer & Scott, 1994). Knowledge is constructed by individuals with the embodiment and/or replacement of prior representations via active participation in the learning process (Minner, Levy & Century, 2010). Therefore, students' existing knowledge about scientific concepts plays a central role in teaching (Limón, 2001) and the fusion of experience and new knowledge is vital for cognitive development (Powell& Kalina, 2009).

As Keys and Bryan (2001) state, cognitive constructivism does not really take into account the social contexts that influence knowledge, and therefore a social constructivist framework is needed. Social constructivism considers learning as a social process that takes into account the learners interaction with the learning environment and the understanding of the social context (Kim, 2001). A social constructivist teacher utilizes the classroom environment and culture to engage learning with students' experiences and interests so that they become competent constructors of world awareness (Oldfather, West, White, & Wilmarth, 1999).

Acknowledging this, inquiry aims to change students misconceptions about a scientific concept by providing them with evidence that conflict with the scientifically accepted within social interaction (Keys & Bryan, 2001). Both constructivism and social constructivism value inquiry as a method for creating an effective environment with the students building on their own existing knowledge and the teacher guiding them through that process (Powell& Kalina, 2009).

4. The role of inquiry and inquiry – based learning

IBL aims to provide students with experiences from the physical world that contribute to the development of skills, conceptual understanding and positive attitudes towards science. If there is no active engagement with processes and concepts of science in a science classroom, then students will not truly appreciate science as a way to understand the natural world (Brunsell, 2008). Prior research indicates that inquiry-based instructional practices are more conductive than other forms of instruction in promoting conceptual understanding (Minner, Levy, & Century, 2010). Students that experience inquiry can better apprehend science and its practices (Edelson, Gordin & Pea, 1999).

Inquiry is firmly connected to the acquisition of scientific skills. The research of Gerber, Cavallo and Marek (2001) revealed that students in inquiry classrooms have or develop greater scientific reasoning abilities than students in formal traditional classrooms. IBL is a flexible, student centered process which exploits authentic scientific methods to develop necessary future skills for the modern student such as collaboration, adaptability, imagination and critical analysis of information (Marks, 2013). Students engage in activities of formulating questions that can be answered through their own research and communication with others (Wu & Hsieh, 2006). According to the National Science Foundation (2000), inquiry provides information about the developmental stage of students, enables them to communicate effectively in a social context and to make their own decisions based on information received from their inquiry outcomes.

5. Phases and sub – phases of inquiry activities

IBL is an educational, flexible strategy with phases that are often organized in a cycle and divided into sub – phases with logical connections depending on the context under investigation (Pedaste et al., 2015). This framework entails five general phases (Orientation, Conceptualization, Investigation, Conclusion and Discussion) and seven sub-phases (Questioning, Hypothesis Generation, Exploration, Experimentation, Data Interpretation, Reflection, and Communication). It can be used by teachers in order to conceptualize a structured way to implement inquiry activities in their science classroom.

IBL is not a linear procedure (see Figure 1) and learners should be involved with various forms of inquiry, going through different combinations of the phases, not all of them necessarily (Wu & Hsieh, 2006; Pedaste et al., 2015; Pedaste & Sarapuu, 2014). For example, if the data analysis is not satisfactory enough, students can return to the conceptualization phase and reconsider their question and/or their experimental design. When students come to a conclusion, new questions can be generated and the process starts again in a progressive fashion. A description of the processes that each phase encompasses is provided below and the connections between these processes are presented in Figure 1 (Pedaste et al., 2015).

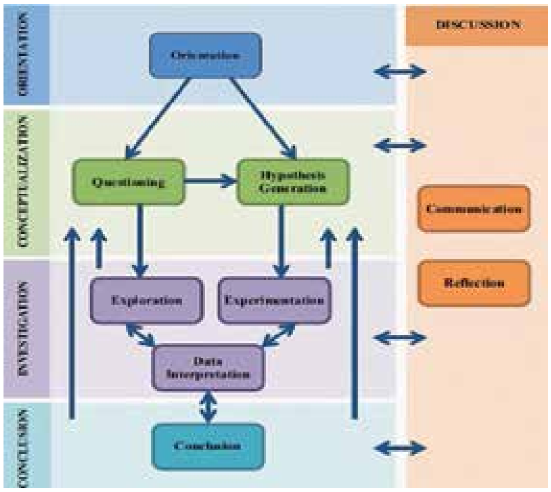

Figure 1. Phases, and sub – phases of Inquiry – based learning and their relations. Excerpted from ''Phases of inquiry-based learning: Definitions and the inquiry cycle'' by Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A., Kamp, E. (2015).

5.1. Orientation

As Mark (2012) states, "student curiosity is at the center of the process" (p. 22). Orientation is the phase where the identification of the problem occurs (Pedaste & Sarapuu, 2014). The topic to be investigated is presented and interest about a problematic situation that can be answered with inquiry is stimulated (Pedaste & Sarapuu, 2014; Pedaste et al., 2015). The topic under investigation must be relevant to students' daily life, interests and prior knowledge.

Teacher's role: Encourages students to express ideas, prior knowledge and questions about the topic, while promoting interaction and communication between them. For example, students can create concept maps of what they know, do not know or want to know about the topic under investigation. These kinds of activities can also be useful for the next phases of inquiry.

5.2. Conceptualization

Conceptualization refers to the understanding of the concept, which relates to the problematic situation presented in the previous phase. It is divided in two sub phases (questioning and hypothesis generation) that lead the learner to the investigation phase (Pedaste et al., 2015).

Teacher's role: *Helps students understand how they can formulate questions and/or hypotheses that can lead to an investigation. If students are not familiar with the questioning and hypothesis generation sub – phases, the teacher can choose a structured type of inquiry at first and then progress in more open types of inquiry in order to provide the appropriate guidance (see section 6).*

5.2.1. Questioning

Questions are formulated in order to design an investigation that produces answers (Marks, 2013). As this skill is developed through inquiry, students can gradually understand which question can lead to investigation and which one is more generative and might lead to different or richer processes (NSF, 2000).

5.2.2. Hypothesis Generation

A hypothesis is generated through providing explanations of how the identified variables relate (Pedaste et al., 2015). It explains how and why phenomenon functions based on former experiences and prior knowledge (NSF, 2000).

5.3. Investigation

Investigation is the phase where students collect evidence in order to answer their questions and/or test their hypothesis (NSF, 2000) and includes the sub – phases of exploration, experimentation, and data interpretation.

Teacher's role: Provides materials that the students might need and keeps them on track so that the process they choose to follow is a process that answers the investigative question. Students should determine what constitutes evidence and collect it. If they are not familiar with this process, a structured type of inquiry can be chosen (see section 6). The teacher can provide or encourage students to create means (e.g. tables, charts etc.) that can help them organize, classify and analyze the data.

5.3.1. Exploration

Exploration is an open process which generates mostly data concerning the identification of a relation between the variables. It is chosen typically when the question that was formed in the previous phase was generative, because students do not have a specific idea of what to explore or how the identified variables relate to each other (Pedaste et al., 2015).

5.3.2. Experimentation

Experimentation includes the design (e.g. choosing the materials and means to measure) and performing of experiments taking into consideration the variables that need to change, remain constant and be measured. The product of this sub – phase are data or evidence that can be used later on for analysis and interpretation.

5.3.3. Data Interpretation

According to the NSF (2000), data interpretation "includes finding a pattern of effects and synthesizing a variety of information" (p. 57). Depending on the concept under investigation and the inquiry procedures that were chosen, finding relations between the variables is sometimes the key for getting the desired outcome (answering the investigative question). Organizing and classifying the data (with graphs, charts, tables, pictures etc.) can benefit this process.

5.4. Conclusion

In this phase students draw conclusions based on the investigative question and the interpretation of the data.

Teacher's role: During this phase, a comparison between the interpreted data and the predictions and initial ideas (that students expressed during the orientation phase) can be stimulated. This process can also lead to new hypotheses and questions about the topic under investigation (as shown in Figure 1).

5.5. Discussion

During the discussion phase students articulate their findings through communicating them to others and/or reflecting upon all or some of the stages of inquiry during the process or by the end of it (Pedaste et al., 2015).

Teacher's role: *Encourages collaboration so that students can present their findings and ideas, provide arguments and give feedback to others. If they are not familiar with these practices, the teacher can provide guidelines that will help them to communicate during all the phases of inquiry.*

5.5.1. Communication

Communication includes discussion with others and representation of results in a manner that is understandable to all (NSF, 2000). It can be applied to a single phase or the whole cycle of inquiry and is usually an external process (Pedaste et al., 2015).

5.5.2. Reflection

In this sub – phase students reflect on their work, their results and the concept under investigation. Reflection can even give rise to new thoughts regarding the inquiry cycle or a single phase (Marks, 2013).

6. Types of inquiry

The types of inquiry vary so that students are actively involved in the process to the extent that they are competent and able to do so. The type of inquiry a teacher may choose to follow is highly depended on the objectives of the lesson, the age of the students, their previous involvement with inquiry and the scientific skills they have already acquired. As shown in Figure 2, the more responsibility the student has, the less direction is provided and more open the inquiry becomes (NRC, 2000).

Learner self-direction →

← Teachers' guidance

Essential Features	Structured	Mixed	Guided	Open
1. Learner engages in scientifically oriented **questions**	engages in question provided by teacher, materials, or other source	sharpens or clarifies question provided by teacher, materials, or other source	selects among questions, poses new questions	poses a question
2. Learner gives priority to **evidence** in responding to questions	given data and told how to analyze	given data and asked to analyze	directed to collect certain data	determines what constitutes evidence and collects it
3. Learner formulates **explanations** from evidence	provided with evidence and how to use evidence to formulate explanation	given possible ways to use evidence to formulate explanation	guided in process of formulating explanations from evidence	formulates explanation after summarizing evidence
4. Learner connects **explanations** to scientific knowledge		given possible connections	directed toward areas and sources of scientific knowledge	independently examines other resources and forms the links to explanations
5. Learner **communicates** and **justifies** explanations	given steps and procedures for communication	provided broad guidelines to use sharpen communication	coached in development of communication	forms reasonable and logical argument to communicate explanations

Figure 2. Types of inquiry and their features regarding questions, evidence, explanations, connection of the explanations to scientific knowledge and communication. Adapted from Inquiry and the National Science Education Standards, NRC (2000) p. 29

The variations of inquiry types concern the increasing or decreasing involvement of the teacher and student in the process. Structured inquiry is directed from the teacher so that students reach a specific result (Colburn, 2000), whereas in mixed inquiry students are more involved during an investigation with the teacher guidance still being the most dominant. These forms of inquiry usually are chosen when students are first introduced to inquiry practices and when there is a focus in the development of a specific skill or concept. Open inquiry provides more opportunities for developing scientific skills (NRC, 2000), given that during open inquiry the students work directly with the materials and practices in a way that resembles authentic scientific approaches.

For example, if students lack previous experiences with designing investigations and collecting data, a more structured or guided form of inquiry should be chosen. When students acquire the skills needed, they can progress to more open inquiry activities. Students should at some point participate in all the forms of inquiry (NRC, 2000), while gradually moving from one form of inquiry to another with the simultaneous progression of complexity and self – direction (Bell, Smetana & Binns, 2005).

7. Combination of physical & virtual manipulatives within the context of the SSE project

Educational material and learning opportunities that support and promote IBL can be developed with the use of physical and/or virtual manipulatives. The term *virtual manipulatives* refers to the use of computer programs (e.g. simulations, virtual labs) with the interaction of the keyboard and the mouse with the computer screen, whereas the term *physical manipulatives* refers to the use of real materials (Zacharia, Loizou & Papaevripidou, 2012).

Both manipulatives can be effective depending on the context and the way they are used. On the one hand, physical manipulatives promote the designing of investigations and the use of real scientific devices that can lead to a better understanding of a phenomenon (Smith & Puntambekar, 2010). On the other hand, virtual manipulatives can ensure efficiency, minimization of errors, safety and reality adaption (De Jong, Linn, & Zacharia, 2013). The use of virtual manipulatives has received increased attention for supporting inquiry in science classrooms and promoting learning (Edelson, Gordin & Pea, 1999). When a scientific concept is not directly observable, such as the concept of earthquakes, technology offers opportunities for experimentation and exploration of the phenomenon.

Each manipulative has its own affordances that affect the process and the outcome, but both can promote IBL (Zacharia & Olympiou, 2011). During the SSE project a combination of the two manipulatives is anticipated for implementation in order to provide a variety of experiences that promote scientific literacy. The project aims at a close collaboration with established EU funded educational projects on inquiry learning at schools, such as Inspiring Science Education (http://www.inspiringscience.eu), Global Online Labs for Inquiry Learning (http://www.go-lab-project.eu) and Ark of Inquiry (http://www.arkofinquiry.eu).

During the SSE project a collection of online and offline educational resources will be utilized to facilitate the inquiry phases of investigation and exploration and promote virtual and physical experimentation. These include scientific simulations, animations, repositories of real earthquake data, specialized software for data analysis and process-ing in combination with scientific instruments, such as educational seismographs or operational real-time seismometers installed or distributed to partners and schools by NOA within the framework of the SSE project. More detailed information, guidelines, user's manuals and examples of usage will be included in the Intellectual Outputs 3 and 4, Implementation Guide and Seismology Handbook, respectively.

8. Three - component pedagogical framework

In the SSE project, a pedagogical framework is suggested for development to serve as a guide in assisting teachers in planning and implementing inquiry lessons and activities within their science classrooms. The framework is built around three components, which are as follows:

a) Project-mapping with the school curricula of the national educational systems of the participating countries
b) Determining the educational and pedagogical role of the teachers leading the students' teams involved
c) Further sound concepts and tools for the development of additional inquiry based learning scenarios in order to enhance the learning experience of students in the school teams participating

An elaboration on each of the three components of the Pedagogical Framework is provided in the subsequent sections.

8.1. Project-mapping with the school curricula of the national educational systems of the participating countries

The five countries that participate in the SSE project are Bulgaria, Cyprus, Greece, Italy and Turkey. These countries have been chosen because of the frequent seismic activity and the past experience in such physical events. Therefore, the concept of earthquakes is useful, interesting and essential for the communities and schools of these countries. Each country has its own national educational system that defines the school curricula and hence the teaching of the concept of earthquakes. The basic information (school level, age, grade, teaching approach, competences, types of activities and evaluation) regarding each country's curricula for the concept of earthquakes is provided in the five Tables beneath.

The teaching approach that is indicated as optimal in these five countries is the investigation oriented approach. The concept competences are correlated with this approach and depend on the school level and age of students. The concept competences in all countries curriculum units focus on the generation of knowledge about the effects of an earthquake and its impact/risk in relation to their country. Also, some countries objectives deal with matters of the generation of an earthquake (e.g. Cyprus and Greece) and/or about the means that are used in seismology (e.g. Turkey and Italy). The skill competences of all countries refer to the promotion of scientific literacy. The types of evaluation that are indicated from the national science curriculum of each country are formative and final evaluation through various means is suggested.

Based on the analysis performed from the information provided by each participating country, the concept of earthquakes has a frivolous place in the national curricula and it is usually not addressed interdisciplinary. The concept requires knowledge from different scientific areas and can be therefore utilized in various contexts and studied as a STEM (Science – Technology – Engineering - Mathematics) subject. The integration of these approaches improves students learning and attracts their interest (Becker& Park, 2011; Sanders, 2009).

<table>
<tr><th colspan="4">Mapping the earthquakes with the national curriculum of Bulgaria</th></tr>
<tr><td>Domain:</td><td colspan="3">Environment (for Primary school), Geography (for High school)</td></tr>
<tr><td>Sub – domain:</td><td colspan="3">Disaster protection (for Primary school and High school)</td></tr>
<tr><td>School level: Primary school, High school</td><td colspan="2">Age: 8 (primary), 15 (high school)</td><td>Grade: 2nd grade, 9th grade</td></tr>
<tr><th>Teaching Approach</th><th>Competences
of the curriculum units</th><th>Types of activities
(brief description)</th><th>Evaluation
(type & means of evaluation)</th></tr>
<tr>
<td>Due to the relatively small age the teachers use a variety of methods to gain students attention: Storytelling, explanation, demonstration of action, visualization, observation, comparison, discussion, association, working in groups and role games.

Recommended is also the use of pictures, photos and posters as supporting tools

<u>Example (earthquakes):</u>
Position: Sofia Bulgaria, 1858
Tools: Stories, descriptions
Theme: Disaster protection
Theories: Safe behavior
Terms: Vibrations, earthquakes, earth layers, destructive actions, relief, evacuation, disaster
Skills: to identify, to describe, to count, to follow the rules, to work in teams</td>
<td>2nd grade

Concept competences:
Students acquire knowledge about the nature and characteristics of the earthquake as an unexpected disaster with great speed and varying destructive power - sounds flutter to the ground, movement of the earth's crust; the students acquire knowledge about the dangers caused by the earthquake disaster;
Students acquire rules of safe behavior before, during and after an earthquake; consolidation of knowledge about precautions to reduce the risk of injury and infection; practical utilization of the Action Plan in an earthquake, acquainted with how to leave safely and immediately from the building after the first quake.

Skills competences:
Various, depending on the role games and simulations

<u>Skill competence example:</u>
Recognizes the earthquakes by their characteristics (sounds that accompany the flutter and movement of the earth's crust, time for destructive actions - 10 sec.);
describes possible damage due to the earthquake, which characterize it as a natural disaster; comply with the instructions of the teachers, guidance on radio, television;
directed to the safest places in the building (school, home) and safest route for them; prepare basic necessities and valuables for leaving the building; observe personal hygiene because of the danger of epidemics;
comply with the guidelines for orderly leave from the classroom and the school immediately after the first earthquake at a particular location;
assist in checking that the students are brought out;
knows the main activities and instructions stipulated in the Action Plan in an earthquake.</td>
<td>2nd grade

How can the lesson be conducted? (Information for the teacher)
Knowledge could be enriched through a "brainstorming" - to the question "What do you imagine when you hear the word "disaster?" Count the characteristics that define a natural phenomenon as a disaster.
The introduction of the topic is carried out by the teacher after reading a popular science text.
The discussion is set by the teacher with the question: "Which natural phenomenon is described in the text?"
During the discussion the teacher can clarify what is the center of an earthquake (epicenter) and the Science that deals with these issues (seismology). The discussion continues by focusing on the list of characteristics that classifies the earthquake as a disaster.
The topic of discussion is directed to the occurrence of earthquakes both on land and in seas and oceans.
Students' attention is drawn to the fact that this natural phenomenon cannot be predicted and prevented. Its duration is not long, but the consequences are severe. To avoid casualties and heavy material damage the state authorities need to take action. Particular attention is paid to the fact that the proper communication can be life-saving.
With group work named: "What should we do in an earthquake situation?" engage the attention of all students and provoke their activity. Each group must submit its task solution in an attractive way: short show, album of paintings, poster paper. At the discretion of the teacher, analysis of the work of the groups and the improvement of their knowledge can be accomplished in two ways:
Read the rules proposed by the responsible state institutions and compare them with the solutions proposed by the groups.
Students work with photos, make verbal description of the possible damages caused by the earthquake and use some of the previously proposed by the teacher's words to compile an oral story.
At the discretion of the teacher the term "evacuation" is clarified and rules for safe removal of students from school are recalled.</td>
<td>The success indicators of the Environment curriculum provide the context of evaluation:

→ Formative assessment of the achievement of the lesson/s competences (skills, concepts) and teaching during the learning procedure – students explain what they understand about earthquakes, their reaction and proper behavior, need for preliminary planning for quick evacuation from home or school, survival kits etc.

→ Diagnostic and final evaluation happens progressively according to specific criteria – teachers set specific questions to the students for different phases of the earthquake, proper conduct in each phase, behavior after earthquake situation, potential risks after earthquakes etc.

<u>Examples of means of evaluation:</u>
– observation
– comparison
– role game situation
– self assessment
– teamwork and critical thinking encouragement</td>
</tr>
</table>

Teachers must clarify the causes of various natural hazards (earthquakes, floods, landslides, etc.) and their consequences. <u>Examples of teaching practices:</u> – exploratory learning – problem-solving learning – discussion – teamwork and mutual assistance – situation games Supporting materials – presentations, training videos, schemes and diagrams	**9th grade** **Concept competences:** 1. Identify the different kinds of natural hazards and their causes 2. Tracks map areas with territorial manifestation of spontaneous natural phenomena 3. Awareness of man's dependence upon natural spontaneous phenomenon and the need to combat them	**9th grade** Throughout the course of study the class must go through the following: 1. Define the term "natural hazard" 2. Classify natural risks, depending on the causes of their origin. 3. Made a paper for major natural disasters and their consequences 4. Know the rules of conduct during natural disaster situations 5. Comment the possible forecasting and combat with elemental natural phenomena	The success indicators of the national geography curriculum provide the context of evaluation: → Formative assessment of the achievement of the lesson/s competences (skills, concepts) during the learning procedure: Understanding key new concepts such as: • Natural risk • Classification of natural hazards • Monitoring Raising awareness about existing opportunities for cross-curricular links: physics: electromagnetic waves; epicenter etc. → D iagnostic and final evaluation happens progressively according to specific criteria <u>Examples of means of evaluation:</u> -observation -brain attack - understanding of thematic maps - active attitude to the problem - self assessment

<table>
<tr><th colspan="4">Mapping the earthquakes with the national curriculum of Cyprus</th></tr>
<tr><td>Domain:</td><td colspan="3">Geography</td></tr>
<tr><td>Sub – domain:</td><td colspan="3">Geology</td></tr>
<tr><td>School level: Primary, Middle school</td><td colspan="2">Age: 11-14</td><td>Grade: 6th – 8th grade</td></tr>
<tr><th>Teaching Approach</th><th>Competences
of the curriculum units</th><th>Types of activities
(brief description)</th><th>Evaluation
(type & means of evaluation)</th></tr>
<tr>
<td>Investigations with the use of tools (e.g. maps, photographs, charts, computer simulations) that are taught to students, used and/or made by students. The lessons are structured based on titles that derived from different sections (position, tools, theme, theories, terms, skills). Teachers must take into consideration the success indicators of the national geography curriculum. Skills are the guide for the organization of the activities.

<u>Example (earthquakes):</u>
Position: East Asia
Tools: Small scale maps, photographs, videos
Theme: Geology
Theories: Tectonic processes
Terms:Tectonic plates, earthquakes
Skills: Influence zone, relationships, district</td>
<td>6th grade

Concept competences:
– Explain that the Earth's crust consists of a number of tectonic plates
– Conclude from maps that the boundaries of tectonic plates are associated with seismic zones

Skills competences:
Numerous skills are mentioned in the curriculum. Teachers choose skills, attitudes and behaviors they want to develop.

<u>Skill competence example:</u>
– Handle digital globe and maps</td>
<td>6th grade

Due to the reformation of the national curriculum, new books were developed, for now only for the first four grades of primary school. Therefore, there is no correlation between the curriculum competences and the activities that are embedded in the 6th grade book. Earthquakes are only briefly mentioned in a chapter about Japan without the direct involvement with the subject.</td>
<td>The success indicators of the national geography curriculum provide the context of evaluation

→ Formative assessment of the achievement of the lesson/s competences (skills, concepts) and teaching during the learning procedure

→ Diagnostic and final evaluation happens progressively according to specific criteria

<u>Examples of means of evaluation:</u>
– observation
– creation/comparison/ understanding of thematic maps
– portfolio
– self assessment
– diagnostic tests</td>
</tr>
<tr>
<td>Teachers must take into consideration the success indicators of the national geography curriculum. Skills (Geo–literacy, epistemological adequacy) are the guide for choosing a teaching approach and practices that define classroom organization, tools and teacher and students role.

<u>Examples of teaching practices:</u>
– exploratory learning
– problem-solving learning
– collaborative learning (constructivism)
– Investigations
– field Research</td>
<td>7th grade

Concept competences:
– distinguish a natural hazard from a natural disaster
– recognize and name natural hazards and disasters that threaten and affect the planet
– mention and describe ways to deal with emergency situations in personal, local and national level
– criticize the power of media to choose and present natural disasters</td>
<td>7th grade

Small thematic chapters that refer to:
– what is natural danger and natural disaster (e.g. .earthquakes, tsunamis, interaction between disasters)
– meet EMAK (Special response unit for disasters)

With gap filling exercises and questions after each chapter</td>
<td>The success indicators of the national geography curriculum provide the context of evaluation

→Formative assessment of the achievement of the lesson/s competences (skills, concepts) and teaching during the learning procedure.

→Diagnostic and final evaluation happens progressively according to specific criteria

<u>Examples of means of evaluation:</u>

– observation
– creation/comparison/ understanding of thematic maps
– portfolio
– self assessment
– diagnostic tests</td>
</tr>
<tr>
<td></td>
<td>8th grade

No specific concept competences were written for the 8th grade because Cyprus geography is no longer part of the school curriculum due to a reduction in the teaching hours of the subject.</td>
<td>8th grade

Small thematic chapters that refer to:
– structure of earth
– description of tectonic plates movements
– creation of Cyprus
– types of stones

With gap filling exercises and closed questions after each chapter</td>
<td></td>
</tr>
</table>

<table>
<tr><th colspan="4">Mapping the earthquakes with the national curriculum of Greece</th></tr>
<tr><td>Domain:</td><td colspan="3">Geography (for Primary and Middle schools), Physics (for High school)</td></tr>
<tr><td>Sub – domain:</td><td colspan="3">Geology (for Primary and Middle schools), Physics(Motion and Velocity, Waves)</td></tr>
<tr><td>School level:
Primary school, Middle school, High school</td><td colspan="2">Age: 6 – 12 (Primary), 12 – 15 (Middle),
15 – 18 (High)</td><td>Grades (that SSE project may be applied):
5th grade, 1st and 2nd grade, 1st grade</td></tr>
<tr><th>Teaching Approach</th><th>Competences
of the curriculum units</th><th>Types of activities
(brief description)</th><th>Evaluation
(type & means of evaluation)</th></tr>
<tr><td>Investigations with the use of multimedia and tools including maps, satellite photographs, computer simulations and animations that are demonstrated and taught to students, used and manipulated or made by students. Traditional lessons of expository instruction by teachers may be complemented by hands-on activities for students within the school classroom and regular time-schedule or out-of-school activities such as a field trip or visit to a natural history or geology museum

<u>Example (earthquakes):</u>
Position: Mediterranean area
Tools: scale maps in paper or electronic format displayed by projector ,other multimedia resources like photographs, videos
Theme: Geology and Geography
Theories: Tectonic processes
Terms: Tectonic plates, earthquakes, seismicity, volcanic activity</td><td>Primary school, 6th grade
Middle school, 1st and 2nd grade

Concept competences:
– Explain that the Earth's crust consists of a number of tectonic plates
– Explain what is an earthquake
– Conclude from maps that the boundaries of tectonic plates are associated with seismic zones
– Natural phenomena and impact

Skills competences:
– Handle scale maps and globe
– distinguish a natural hazard from a natural disaster
– recognize and name natural hazards and disasters that threaten and affect the planet
– explain what their impact to society, to ecosystems etc. is
– mention and describe ways to deal with emergency situations in individual, local and national level</td><td><u>Example of related activities:</u>
– students make thematic projects
– school or classroom visit to a natural history or geology museum
– identification of different types of stones and their origin
– creation of our country's landscape, mountains, islands etc.
– earthquake awareness day, what do we do in case of an earthquake, -video or documentary movie presentation discussion and reflection</td><td>The national science/geography curriculum describes the general framework of student assessment and evaluation of the learning procedure. It includes: formative assessment, diagnostic evaluation and monitoring, and final evaluation

<u>Examples of means of evaluation:</u>
– questioning and observation
– creation/comparison/ understanding of thematic maps
– diagnostic tests
– interim and final exams, summative assessment</td></tr>
<tr><td>Teachers take into consideration the learning success indicators of the national geography curriculum. Students skills developed include geo–literacy, geo-spatial thinking, awareness of natural phenomena and their impact. Teachers choose teaching approach and practices for classroom organization, activities, tools and students' role taking into account available curriculum flexibility with respect to time and resources

<u>Examples of teaching practices:</u>
– exploratory learning
– investigations and field research
– collaborative and inquiry learning</td><td>High school, 1st grade

At high-school level Geology and Geography subjects are not in the science curriculum. However the study of the theme of earthquakes gives a lot of opportunities for interdisciplinary teaching and learning within the subjects of Physics and Mathematics/ Geometry/ Statistics. In particular earthquakes, their creation and propagation, can be related to the concepts of Motion and Velocity, Waves and their Propagation, Triangulation etc.

Within this context

Concept competences:
– What is an earthquake and how do we measure its parameters
– What is seismic wave
– Natural phenomena, natural disasters and impact. How to protect from, how to react to

Skills competences:
– Handle and understand scientific data
– operation of a scientific instrument
– collection and analysis of data, scientific inquiry, make hypothesis, do investigation and research, conclude from evidence
– increased awareness about natural disasters, threats and risks and impact
– (in case of assignment of project work to groups of students) skills of collaboration, communication, presentation</td><td><u>Example of related activities:</u>
– students make thematic projects related to earthquakes.
– students collect and analyze earthquake data from online repositories or seismometers
– students make a video or presentation related to recent earthquakes in the country or around the world and their impact to society and the environment (e.g. destruction of the Fukushima nuclear reactor, impact of tsunamis etc)</td><td></td></tr>
</table>

Mapping the earthquakes with the national curriculum of Italy			
Domain:	Science, physics		
Sub – domain:	Earth science		
School level: High school	**Age:** 14 – 18		**Grades:** 9th - 13th grade Related topics in more depth: 12th & 13th grade
Teaching Approach	**Competences of the curriculum units**	**Types of activities (brief description)**	**Evaluation (type & means of evaluation)**
The study of seismology is taken on more or less in depth depending on the curricular background of the teacher. In general is less significant than chemistry or biology as well as laboratory experimental activities. Several Italian teachers in science attend training and teaching experiences about non formal education of seismology in the framework of related educational projects and in this case maybe their students are involved in experimental experiences.	**Concept competences:** – Earthquake definition – Where and why earthquakes occur (earthquakes distribution on Earth's surface, relationships between earthquakes and tectonic plates etc.) – How earthquakes are generated (focal mechanism, mechanical behavior of rocks, kinds of faults, typologies of seismic waves and their propagation). – How to record an earthquake: devices and data. – Seismographs, mean and interpretation (pattern and duration depending on distance and magnitude etc.) – Measure of earthquakes (intensity MCS, magnitude and momentum magnitude) – Seismic risk with a particular focus on Italian territory, earthquakes forecast and prediction – Direct effects of earthquakes (ground shaking and buildings fall), indirect effects (tsunamis, landslides, liquefaction of sands, etc.). **Skills Competences:** – To know what an earthquakes is and contextualize this phenomena in the wider framework of Earth's crust dynamics – To know the means of such Earthquakes related definitions as different kinds of fault, different ground motions, direct and indirect effects of an earthquakes, etc. – To know the main tools and devices aimed to get seismic data and their working, and be able to interpret, at least in a descriptive way, these data – To be aware of seismic risk, with a particular focus on the risk in the territory where they live, and of a correct behavior in case of earthquakes	– Frontal lesson and consequential study on textbooks. – Some laboratorial experiences can be applied if the teacher is particularly interested to seismology (because of background, interest or training project attendance). In this case students can be involved in such activities like the ones envisaging the use of ICT exploiting resources and data available online or even the assembly of technical devices such as educational seismographs. However these cases can be still considered as exceptions.	According to the program indications in science by the Italian Ministry of Education, students should attend periodical evaluation tests. The main Italian school publishers provide teachers with thematic test models in curricular subjects

<table>
<tr><th colspan="4">Mapping the earthquakes with the national curriculum of Turkey</th></tr>
<tr><td>Domain:</td><td colspan="3">Science</td></tr>
<tr><td>Sub – domain:</td><td colspan="3">Physical Events</td></tr>
<tr><td>School level: Secondary school</td><td>Age: 13 – 14</td><td colspan="2">Grades: grade 8</td></tr>
<tr><th>Teaching Approach</th><th>Competences
of the curriculum units</th><th>Types of activities
(brief description)</th><th>Evaluation
(type & means of evaluation)</th></tr>
<tr><td>The planning and application of lessons are based on learning environments in which the students are active and the teachers are facilitators. For meaningful and permanent learning of the information in the field of science, in-class and out of school learning environments are designed according to inquiry-based learning strategy for students. In this regard informal learning environments like science, art and archeology museums, zoos, natural environments are also used.

The process of research and questioning is not only regarded as exploration and experiment but also the as process of explaining and creating arguments. In short, the students create the information in their own minds by practicing-experiencing-thinking like scientists. Teachers allow their students to take part in dialogues through which they can articulate their ideas, support their thoughts with different justifications, and develop opposite dissertations to refute their friends' theses. In discussions, students present their claims with justifications which they create through valid data. Teachers take the role of guiding directors in these written or verbal discussions that have opposite theses.</td><td>Competences:
– define general concepts on seismology such as seismologist, aftershock, foreshock, intensity of earthquake, fault line, fault line break, earthquake zone;
– describe that seismology is a science field and the scientist working in this field is called seismologist;
– make a connection between Turkey's earthquake zones and fault lines;
– argue about reasons of earthquake and emergent adverse outcomes;
– state that not only fault lines but also volcanic eruptions cause earthquakes;
– discuss precautions against the risk of earthquake, and things to be done during an earthquake.</td><td><u>Example of related activities:</u>
– Reading the news on the newspapers and internet about the big earthquakes in Turkey in the classroom.
– Watching a movie of how earthquakes happen
– Using play dough to demonstrate plate movements
– Students are given an investigation to search what can be done before, during and after earthquakes and then explain these precautions in the classroom.</td><td>In the science curriculum, an assessment approach which serves for the intention of monitoring and directing students in the process, identifying learning difficulties and elimination of them, supporting meaningful and permanent learning by providing continuous feedback has been adopted. Having a meaning of the numerical values obtained in the result, the monitoring of student progress and the direction of the student according to this progress are among the important principles of the curriculum.

The point of view based on assessment depends on the assessment understanding of evaluating the process as well as product; so it is suggested that together with the learning outcome, the performance of the student should be assessed at the end of the process. It is also suggested that complementary assessment tools and techniques should be used since the numerical values obtained through traditional assessment tools do not have a meaning alone.

By the use of complementary assessment tools and techniques process oriented assessment approach is emphasized. Self-assessment and peer assessment approaches by which the student has the chance of evaluating himself and his friend are adopted. Also, technology is used in order to monitor and assess the learning process of students and their performance at the end of this process.</td></tr>
</table>

The activities and educational approaches, that are briefly descripted in the Tables above, provide a space of freedom to teachers to choose how and when to integrate their selected activities into their teaching practice and the types of evaluation and teaching methods to follow. However, while the curriculum suggests contemporary teaching methods, the teaching materials and the associated activities are mostly text –driven and can be considered as "traditional" (see Cyprus and Italy national curriculum in abovementioned tables for example). Hence, when the teachers are not well informed and trained to implement IBL in their science classrooms, they tend to prefer these traditional approaches, especially for a concept like earthquakes. This particular situation is also aggravated because of teachers' lack of background knowledge and understanding of the means used, such as seismographs and databases. Therefore, the SSE project and its Intellectual Outputs can provide the basic information that a teacher will need in order to design and implement a successful inquiry based lesson.

By reviewing the information that was provided by representative organizations from each country, the significance and importance of the current project's contribution towards approaching the study of earthquakes from an inquiry-oriented perspective is prevalent. The SSE project provides the opportunity to educational systems and schools of the participating countries to integrate and study earthquake concepts within the context of their science curriculum. In addition, the SSE project aims to facilitate cooperation and relations between their schools and communities. The teachers can then use this network to enhance science lessons (with materials, equipment and other means), motivate students, renew educational methods and improve the quality of teaching.

8.2. The educational and pedagogical role of the teachers leading the students involved

Any science education teacher has a flexible and guiding role in the process of inquiry by providing a suitable learning environment that focuses on the learning process rather than the knowledge acquisition (Marks, 2013). Inquiry sometimes might be challenging for students. By providing a variety of stimuli and activities that meet students' pre-existing knowledge and learning style, a teacher creates learning experiences that are needed in order to understand how the world functions (NSF, 2000). The learning process is centered on the participation in basic inquiry tasks such as formulating questions, identifying variables, conducting experiments and drawing conclusions.

A teacher must possess skills and certain attitudes in order to encourage and support IBL (Colburn, 2000; Maaß & Doorman, 2013) in his/her own practice. The NRC (2000) refers to six standards that focus on inquiry classrooms. Inquiry is strongly aligned with these standards. They refer to practices a teacher should adopt and implement in order to ensure that students are involved in effective science activities, which interest them and provide them with the best opportunities for developing knowledge and skills.

A science teacher:

a) Plans an inquiry-based science program for their students

b) Guides and facilitates learning

c) Engages in ongoing assessment of teaching and of student learning

d) Designs and manages learning environments that provide students with the time, space, and resources needed for learning science

e) Develops communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning

f) Actively participates in the ongoing planning and development of the school science program.

(NRC, 2000, pp. 22 - 23)

Within the context of the SSE project, teachers must not only be able to aid students during the process of gaining skills and knowledge but also, because of the nature of the concept, to promote citizenship and civil responsibility. Earthquakes constitute a real world problem that connects with public awareness and civil protection. Therefore students must consider the societal impact of earthquakes while getting involved with activities that promote the improvement of problem solving skills and collaboration.

8.3. Further sound concepts and tools for the development of additional inquiry based learning scenarios

Approaching the study of earthquakes through an inquiry-driven approach requires quite often the construction of models or the use of ready-made models and/or simulations. This stance departs from the notion that the phenomenon of an earthquake occurs in a limited amount of time and thus inferences about the characteristics of the earthquake (e.g., earthquake's magnitude, nature, etc) can be drawn through the study of data collected with the use of specially designed devices such as seismographs. By analyzing the collected data, individuals seek to understand the mechanism through which the earthquake occurred and in doing so, they create models as means to represent and explain the phenomenon and at a later stage use them for formulating and testing of predictions for possible future earthquakes. This process reflects the process of modeling that is followed in order to improve our understandings about aspects of certain physical phenomena.

Consequently, modeling represents an authentic *scientific enterprise*, since scientists develop models in order to build and elaborate their own understanding about their research domains. In addition, modeling could be viewed as an instructional approach, when used as a platform to help students develop understanding of the content, the process, and the epistemology of science through building, testing, refining, and validating models of observed phenomena or complex systems.

Model building is in line with constructionist theories of learning (Papert, 1991); in order to build an internal, mental model of a particular scientific phenomenon, learners need to construct external representations or artifacts of the phenomenon under study, and as Jackson (1995) put it, "to develop that level of understanding, students need to engage in the activities of modeling, e.g., questioning, predicting, constructing, verifying" (p. 7). Modeling activities provide opportunities for teachers' to better monitor students' progression from their initial and probably naive understanding of a phenomenon or a concept under study to a more comprehensive and epistemologically acceptable conception of these phenomena and concepts. Additionally, engaging students in the iterative and cyclical processes of model development and deployment would enable them to: (i) express and externalize their own internalized mental models and thus to express their own thinking; (iii) examine abstract scientific phenomena in a way that meets their cognitive ability; (iv) solve problems; (v) coordinate and integrate facts with scientific theory rather than passively collect facts and formulas, etc.

Following Rogat's et al. (2006) recommendations of how learners can be engaged in meaningful modeling processes, the following modeling practices can be integrated within the context of the SSE project:

a) **Construct (develop models):** Learners use data collected through a seismograph to construct a model of an earthquake. In their model, they might seek to represent the phenomenon under study and provide a mechanism that explains how the phenomenon functions.

b) **Use (explain, test, and predict through the use of a model):** Learners use ready-made models to explain how an earthquake occurred (e.g. identification of the mechanism that controlled the behavior of a certain earthquake), or use a model to formulate and test of predictions for future earthquake activity.

c) **Evaluate (identify limitations, determine explanatory power):** Learners evaluate their own evolved models or ready-made ones on the basis of certain criteria, e.g., model's *representational complexity* (e.g., does the model represent the phenomenon under study?), *explanatory potential* (e.g., does the model provide a possible mechanism that helps in explaining how and why the phenomenon functioned the way it did?) and *predictive power* (e.g., does the model allow the formulation and testing of predictions for phenomenon's future behavior?).

d) **Revise (revise a model to strengthen its explanatory power):** Learners revise their own models or ready-made models after comparisons made with the physical phenomenon they relate to and on the basis of certain criteria such as model's representational complexity, explanatory potential, and predictive power.

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Implementation Guide

1. Indroduction

The Implementation Guide considers three topics regarding the "Schools Study Earthquakes" (SSE) project: the overall application, the educational intervention and the evaluation of the project. The aim is to create a guide for the participating teachers through which they will be scaffolded on how to use the teaching materials (e.g., curriculum activities, educational scenarios, etc.) and related equipment (e.g., seismographs, data analysis software, etc.) in their teaching practice. Furthermore, due to the diversity of the participating countries, issues that concern different educational methods and approaches will be addressed, as well as problems and solutions for various matters that appeared during the life of the project.

2. Implementation of the SSE project in schools

The partners of the SSE consortium soon after the completion of the guides, handbooks and training materials launched an open call/invitation to the community of schools and science teachers of their country to officially join and participate in the project. The teachers and schools selected by each partner formed the school network of SSE. The main task of the participating teachers was to implement in their classroom practice an educational scenario, lesson plan or activity related to earthquakes. They had the opportunity to adopt a ready-made one, as those described in this document, or adapt it accordingly or/and develop new ones. Participating teachers were provided with a comprehensive set of training and support materials produced by the project partners, namely "Pedagogical Framework", "Seismology Handbook", and "Implementation Guide", and they also had the opportunity to attend induction and practice workshops organized by the partners. After the in-classroom implementation the participating teachers and their students provided their feedback, though standardized means (paper questionnaires), on various aspects of the project (e.g. proposed pedagogical framework based on inquiry, overall project approach and methodology, evaluation of students' attitude towards sciences, etc.) so that the project's impact and efficiency could be evaluated and assessed. The teachers and schools received certificates of participation in the "Schools Study Earthquakes" Erasmus+ project.

3. Teaching Intervention

During the SSE project the teachers will implement lesson plans developed by the partners or adapt and develop their own. Before an educational intervention, a teacher should follow some steps in order to implement an effective lesson (see Figure 1). This application refers to the SSE project but it can also be used by teachers, schools and communities that wish to work with similar projects.

As shown in Figure 1, the teacher must be **familiar with the context** of the project. Earthquakes can be introduced through several fields that are part of the school curriculum such as mathematics, geology, physics and geography. In doing so, students are expected to develop interest in STEM subjects (Science – Technology – Engineering – Mathematics) and understand the concept in a unison manner. Additionally, to design an effective lesson plan, a teacher should be acquainted with **knowledge about the educational approach to be followed** and **students' familiarity with the context of the approach,** in order to design a learning activity sequence for approaching the study of earthquakes through inquiry. As indicated in the "Pedagogical Framework" (Intellectual Output 1 of the SSE project), the objectives of the lesson, the age and the former experience and skills of students play a significant role in choosing the type of inquiry and the combination of phases the teacher will follow.

All considerations that the teacher goes through highly affect the planning of the lesson. First, the teacher **designs the activities** taking into consideration the **time** at his/her disposal, the objectives of the lesson that relate to the project's objectives and **how students' learning outcomes will be evaluated** (type and means of evaluation). The **objectives that relate to the educational approach** concern the development of scientific skills, such as observing, questioning, investigating and communicating, and can be gained through inquiry – based learning. The educational approach also provides insight in **students' and teachers' role**. Inquiry – based learning is a learner centered approach with the teacher having a guiding role that increases or decreases depending on the type of inquiry. More information regarding inquiry – based learning can be obtained from the "Pedagogical Framework" (see Intellectual output 1 of the SSE project).

Concerning the **objectives that refer to the context**, teachers should take into consideration the success indicators of their national curriculum. In general and within the context of the SSE project, students should learn in depth specific topics of physics and geology such as Earth's layer construction, what is an earthquake and what causes it, the types of seismic

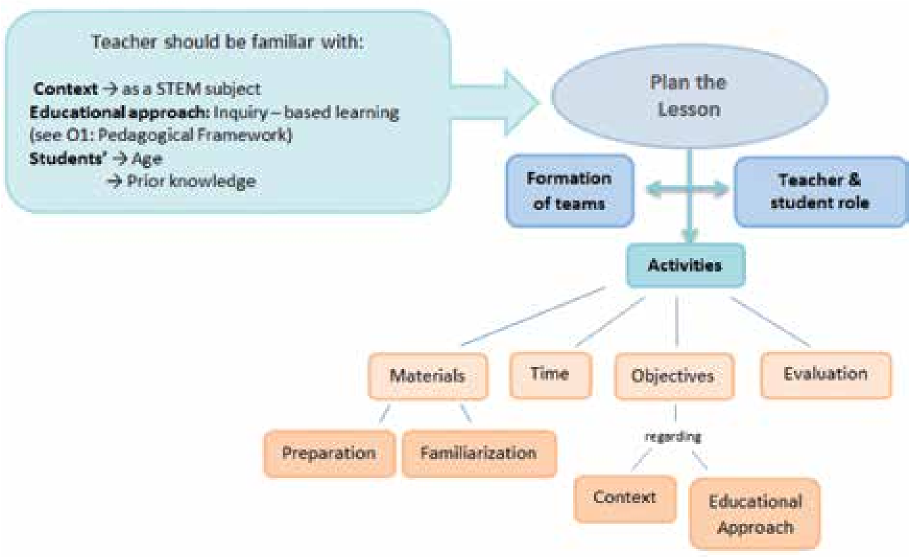


Figure 1. Steps the teacher follows for planning a lesson in line with the SSE project

waves, wave propagation, the main parameters of an earthquake event (location, depth, magnitude) and how to calculate it with the use of a typical seismogram, etc. For the SSE project, the seismographs will be first installed and then teachers and students will familiarize themselves with their operation system. Teachers should also prepare and get familiar with other **materials** that they will be using, such as computer-based tools and activity sheets and/ or physical manipulatives and equipment.

During a lesson, the motivation of the students comes first (orientation phase). It can be accomplished with the use of videos, presentations, discussion, etc. to enhance their interest in the context of the lesson. The activities to follow must have a logical order, learning progression and reference to the authentic practices of scientists (inquiry phases). They should also promote collaboration and discussion **within the formed learner teams** that work together during the inquiry process. The teams, using the seismographs, record and analyze data to calculate earthquakes parameters. Then, they prepare presentations and collaborate during on-line meetings with other school teams that participate in the project by presenting, discussing and exchanging results, experiences and difficulties (once every 2 -3 weeks).

The competences of the application of the SSE project point out the engagement of students with activities that promote scientific skills and model the authentic work of scientists and researchers. Consequently, the students' interest in science can increase, innovative teaching can be motivated and the cooperation between schools can be promoted.

3.1. Lesson plan examples

In the following pages of the Implementation Guide, lesson plan examples concerning the concept of earthquakes, developed by the project's partners, are provided. Each lesson plan was developed in regards to the national curriculum of each participating country. Through the course of the SSE project more lesson plans were added to the Implementation Guide to provide more examples to the teachers. In each lesson plan, basic information is provided in the first page (school level, grade, age of students, approximate time needed for implementing the lesson, domain, sub-domain, classroom organization, concept and skill competences, means and materials needed) and an English introduction if the lesson plan is written in the native language of the country. The activities description that follows is based on the inquiry – based approach. All the material and activities are indicative and should be adjusted to students' specific needs and knowledge about the concept under investigation.

Country	Lesson plan title	Basic information	
		School level	Grade
Cyprus	What is the relation between tectonic plates and earthquakes?	Primary school	6th grade
	Εύρεση επίκεντρου με τη χρήση του SeisGram2K	Middle school	7th-8th grade
	Σεισμικά κύματα (available in the Go-Lab platform) url: goo.gl/BGnCMz	Middle school	7th-8th grade
	Εύρεση επίκεντρου του σεισμού (available in the Go-Lab platform) url: https://goo.gl/lNG4cO	Middle school	7th-8th grade
Turkey	Measuring the earthquakes in Turkey	Middle school	8th grade (13-14 years old)
	Pangea Puzzle	Middle school	6th grade
Bulgaria	Proper behavior in an earthquake situation	Primary school	2nd grade (8 years old)
	How to find the epicenter of an earthquake using modern information technology	Secondary	9th grade (15 years old)
Italy	How to locate the epicenter of an earthquake	High school	8th-13th grade (13-18 years old)
	How to estimate the Magnitude of an earthquake (in Italian)	High school	
Greece	Study of earthquakes	High school	15-18 years old
	Earthquakes and tectonic plates	Junior high school	12-14 years old
	Σεισμοί - Χρόνος και Επίκεντρο	Junior high school High school	12-15 years old 15-18 years old
	Σεισμοί - Δραστηριότητα Χρονομέτρησης	Junior high school High school	12-15 years old 15-18 years old

"What is the relation between tectonic plates and earthquakes?"

The lesson plan was developed according to the Cypriot national curriculum

School level: Primary

Grade, age of students: 6th grade, 11-12 years old

Approx. time needed: 80 minutes

Domain: Geography

Sub-domain: Geology

Classroom organization: Teams of 3-4 students

Concept competences:

- Explain that the Earth's crust consists of a number of tectonic plates
- Conclude from maps that the boundaries of tectonic plates are associated with seismic zones

(Indicative) Skill competences:

- Interpret data from digital globe and maps
- Support their arguments with valid data

Means and materials:

For each student:

- work sheet (you can find an indicative work sheet in the appendix)
- world map that shows the tectonic plates boundaries

For each team:

- computer
- computer programs:
    - google earth
    - google earth KML for:
- Plate boundaries
- Earthquakes from 0-2011

You can download google earth from: https://www.google.com/earth/download/ge/agree.html

You can download google earth KML from: http://earthquake.usgs.gov/earthquakes/feed/v1.0/kml.php https://maps.google.com/gallery/search?hl=el&q=earthquakes

Activities description:

Orientation phase

If an earthquake occurred not a while ago, you can ask your students to mention experiences (what they felt, what and how they think it happened) or you can show a news broadcast about an earthquake event. After that you can ask the following questions: "Do you think earthquakes occur only in Cyprus?" "Where do you think, other earthquakes might occur and why?" "Why do you think we have so many earthquakes in Cyprus?" You can have your students map their ideas about earthquakes and present some of them to the other students.

Conceptualization phase

Show a world map that presents the tectonic plate's boundaries and earthquakes occurrence (e.g. http://all-geo.org/highlyallochthonous/wp-content/uploads/2010/07/globalseis.jpg) and also an image that shows the earth layers (e.g. http://www.worldatlas.com/aatlas/infopage/tectonic.gif). You can have the students ask questions based on their observations, or if they are not familiar with the procedure, you can raise some of the questions. For example: "Where do earthquakes occur in relation to the tectonic plates?" "Why? (Observe the earth's layers)" "Do you think the morphology of the places that earthquakes occur (plates boundaries) is the same everywhere?" "What do you think are the differences/similarities and why?" You can have your students add their ideas on their concept map.

Investigation phase

Each team works in a computer using google earth. Each student can use a world map showing the plates boundaries and the work sheet that is provided in the appendix (you should adjust the work sheet according to your students' needs and knowledge about the concept of the lesson and the processes of inquiry). During the investigation, the children observe a specific place on earth (by using google earth and the world map) and they interpret their observations based on the plates' movements, while explain-

Useful information for the teacher:

– **The lesson plan was developed according to inquiry – based learning (you can find more about it in the Intellectual Output 1 of the SSE project)**

– **If you are not familiar with the use of google earth** you can find out more in this website: https://support.google.com/earth/answer/176576?hl=en

– **If your students are not familiar with google earth** you can provide them with the information needed for the lesson (e.g. screenshots for showing them the steps they must follow) or you can devote some time before the lesson to get your students familiar with the tool

– **If your students are not familiar with inquiry** you can follow a more structured type (e.g. give specific roles to the students of each team, have more structured activities during the investigation phase: provide them data, words they can use to explain certain things, examples, ways to organize their data)

– **If they are familiar with inquiry and /or the concept** you can choose a more open type of inquiry (e.g. they can organize their data in a form they choose is best)

– **If you want to extend the lesson,** here are some suggestions:

- *Volcanoes* (if you want you can develop similar activities like those above. You can add to google earth information about the location of volcanoes by using this hyperlink: https://maps.google.com/gallery/search?hl=el&q=volcanoes. You can also enable the appearance of photos [earth gallery/layers/photos] if you want your students to see and study the morphology of the volcanoes:
  - Where do the most volcanoes form? (Convergent, Transformed or Divergent boundaries?). Explain why.
  - What is the relation between volcanoes and earthquakes occurrence?
- *Creation of Cyprus*
- *Develop models about a specific earthquake event*

ing their reasoning. They follow, more or less, the same procedure for each type of boundary (convergent, divergent and transformed). For more details about the investigation procedure, see the students working sheet in the appendix.

During this phase, the teacher must have a guiding role. You can stop the teams when there is a need to discuss something altogether or you can add specific points to the working sheet so that students will know when they must stop and have a conversation with the whole class or call the teacher for a discussion within the team.

Conclusion phase

Students compare the data they collected during the previous phase with their concept map (initial ideas). They can add/delete/adjust (with a different color) what they have learnt and present it to the classroom (they can also do the same thing after they listen to all the teams or you can have a classroom concept map and teams can add to that).

Appendix

Work sheet (investigation phase) – each student also has a world map that shows the tectonic plates boundaries.

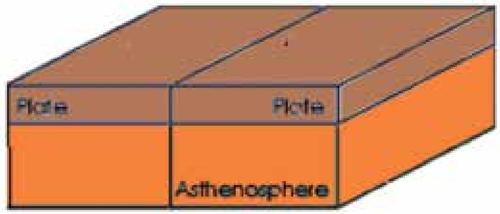
1. Zoom in Cyprus
Do you see something strange? What is the ocean's floor morphology there? *Use your world map to make comparisons.*

....

....

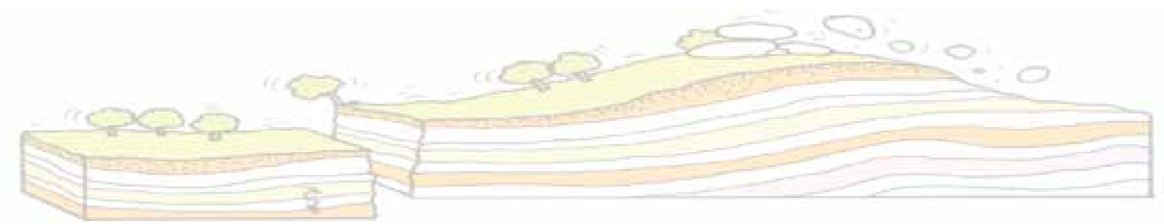
....».

a. Draw arrows to the picture below to show the two tectonic plates (African and Eurasian) move when an earthquake occurs on their boundaries near Cyprus. Explain your reasoning.

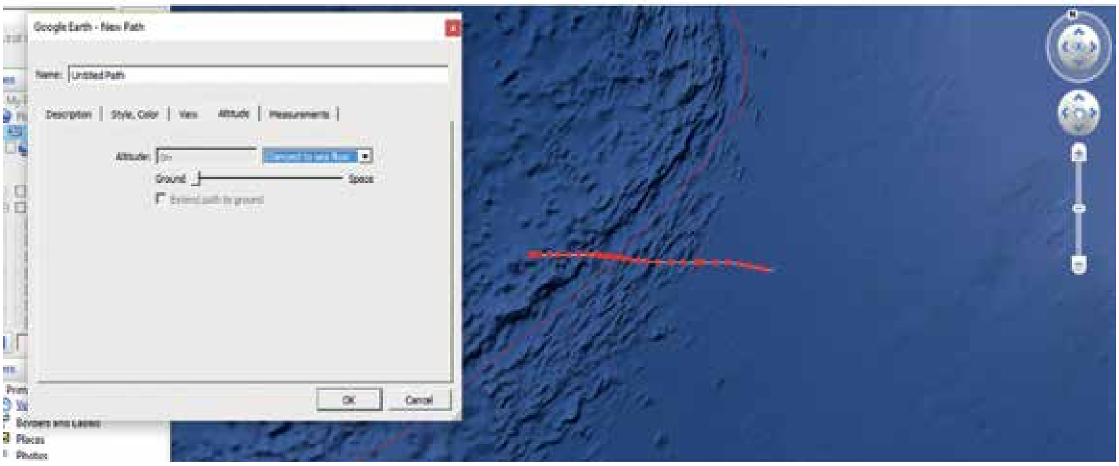


b. Use google earth and draw on your world map with a color where you think similar type of boundaries exists. Explain how you came up with this decision.

c. Enable the tectonic plates KML (Places - on the left of the screen). Compare your observations with your answers above. You can add and/or adjust the lines you draw on your map.



2. Add a horizontal path to a place with divergent boundaries of your choosing (see how you can add a path in the screenshot below). Then click Edit/ Show Elevation Profile.



a. What do you observe?

____

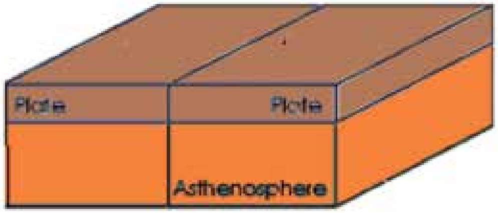
____

b. What is the difference between divergent and convergent boundaries? *If you want you can follow the procedure descripted above for the convergent boundaries.* Why do you think there is a difference?

____

____

c. Draw arrows to the picture below to show how the two tectonic plates move when an earthquake occurs on the divergent boundaries. Explain your reasoning.



____

____

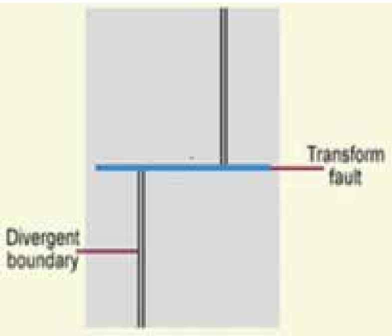
____

3. Visit San Andreas Fault, California

(You can find the place by writing it to the search box on the left of your screen)

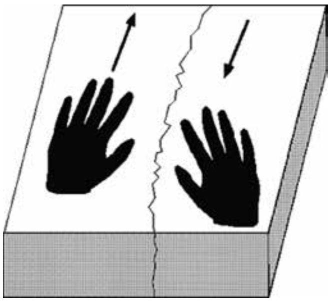
a. What is the ground morphology there? (You can disable tectonic plates KML to take a better look)

Why do you think the ground morphology is that way?



Based on your observations, draw to the picture on the left arrows of how a transform fault moves and explain why you think it moves that way.

Investigate:



1. Ask your teacher to give you two pieces of foam rubber.
2. Place the pieces on your desk and connect their rough edges together. **Each piece of foam rubber represents a tectonic plate.**
3. Push lightly the two pieces, one towards the desk and the other towards you (like the picture).

What do you observe?

…………………………………………………………………………………………………..

Soon a little bit of foam rubber along the crack (the fault) will break and the two pieces will suddenly slip past each other. What does this sudden breaking represents?

…………………………………………………………………………………………………..

Why do earthquakes occur?

____

____

____

____

Based on the data you have collected during this investigation:

* Draw on your world map arrows to show the direction of tectonic plates drift.

* Compare all your data with your concept map (add/adjust what you have learnt with a different color)

*Prepare to present your concept map to the rest of the class

"Εύρεση επίκεντρου με τη χρήση του SeisGram2K"

The lesson plan was developed according to the Cypriot national curriculum

School level: Middle school

Grade, age of students: 7th – 8th grade

Approx. time needed: 80 minutes

Domain: Seismology

Classroom organization: Groups of 2-3 students

Means and materials:

1. Computer (for each group of students)
2. SeisGram2K: http://alomax.free.fr/seisgram/beta/ (SeisGram2K60_SCHOOL.jar)
3. Three seismograms of the same earthquake from different stations
4. Google Earth Pro

Introduction

This lesson plan was designed for middle school grades but with some changes it can be easily implemented in other grades as well. The lesson plan concerns the concept of epicenter and it utilizes technology by using two computer programs: SeisGram2K and Google Earth Pro. Students can work in groups of 2-3 and the teacher can guide them through the process of finding the epicenter of an earthquake. The steps needed for locating the epicenter of any earthquake are given in Greek in the worksheets below (calculation of the distance between the seismic station and the epicenter of the earthquake with the use of SeisGram2K and three seismograms and the localization of the epicenter with the triangulation method and Google Earth Pro). The worksheets give freedom to the teacher to choose which three (or more) seismograms he/she wants to provide to students based on the students' skills and prior knowledge, as well as how recent the seismic event is and the significance of it.

Εισαγωγή

Το μάθημα δημιουργήθηκε για μαθητές γυμνασίου, αλλά με την κατάλληλη διαμόρφωση μπορεί να εφαρμοστεί και σε άλλες τάξεις. Το μάθημα αφορά την έννοια του επίκεντρου με την αξιοποίηση λογισμικών στον υπολογιστή (SeisGram2K, Google Earth Pro). Για την υλοποίηση του μαθήματος, οι μαθητές μπορούν να εργαστούν σε ομάδες 2-3 ατόμων σε έναν ηλεκτρονικό υπολογιστή με τον εκπαιδευτικό να έχει καθοδηγητικό ρόλο κατά τη διαδικασία. Τα φύλλα εργασίας που παρουσιάζονται πιο κάτω περιέχουν τα βήματα που είναι αναγκαία για τον εντοπισμό του επίκεντρου οποιοδήποτε σεισμού (υπολογισμός της απόστασης μεταξύ ενός σεισμολογικού σταθμού και του επίκεντρου με τη χρήση του SeisGram2K και τρία σεισμογραφήματα και εντοπισμός του επίκεντρου με τη μέθοδο της τριγωνοποίησης και του Google Earth Pro). Τα φύλλα εργασίας παρέχουν τη δυνατότητα στους εκπαιδευτικούς να επιλέξουν τα τρία (ή περισσότερα) σεισμογραφήματα με τα οποία θέλουν να εργαστούν οι μαθητές τους, βασισμένοι στις προϋπάρχουσές τους γνώσεις και δεξιότητες, καθώς και στο πόσο πρόσφατος και σημαντικός είναι κάποιος σεισμός.

Εύρεση επίκεντρου με τη χρήση του SeisGram2K

*Για την ανάλυση σεισμογραφημάτων (χρονική διαφορά άφιξης σεισμικών κυμάτων, απόσταση σεισμού από σεισμογράφο) θα χρησιμοποιηθεί το λογισμικό **SeisGram2K.***

Στην επόμενη σελίδα θα βρεις έναν πίνακα στον οποίο θα καταγράφεις τα δεδομένα σου για τα σεισμογραφήματα που αναλύεις στο λογισμικό SeisGram2K. Συμπληρώνοντας τις πληροφορίες που ζητούνται στον πίνακα, θα είσαι σε θέση να εντοπίσεις το επίκεντρο του σεισμού.

1. Για να συμπληρώσεις στον πίνακα την ονομασία και τις συντεταγμένες του σταθμού ακολούθησε την πιο κάτω διαδικασία:

   Άνοιξε το πρόγραμμα. Για να εισάγεις ένα σεισμογράφημα πάτησε File/Select File και επέλεξε τον φάκελο και το σεισμογράφημα (.sac) που θα σου υποδείξει ο εκπαιδευτικός. Πάτησε Open.

   Όταν πατήσεις View/Seismogram info παρουσιάζονται πληροφορίες σχετικά με τον σεισμολογικό σταθμό και το σεισμογράφημα.

   Πώς ονομάζεται ο σταθμός (station) στον οποίο καταγράφηκε το σεισμογράφημά σου; *(συμπλήρωσε την απάντηση στον πίνακα)*

   Ποια ημερομηνία και τι ώρα έγινε η καταγραφή (origin time); ……………………………………

   Ποιες είναι οι συντεταγμένες του σταθμού (station Latitude και station Longitude);
   (συμπλήρωσε την απάντηση στον πίνακα)

Χρησιμοποίησε τον συγκεκριμένο πίνακα για να καταγράφεις τα δεδομένα σου για τα σεισμογραφήματα που αναλύεις στο λογισμικό SeisGram2K:

	Ονομασία σταθμού (station)	Συντεταγμένες σταθμού (station Latitude και station Longitude)	Χρονική διαφορά κυμάτων S και P (Ts-Tp) σε δευτερόλεπτα (s)	Απόσταση (dist.) επίκεντρου από σεισμολογικό σταθμό (km)
1				
2				
3				

2. Για να συμπληρώσεις στον πίνακα την χρονική διαφορά κυμάτων S και P (Ts-Tp) σε δευτερόλεπτα (s) ακολούθησε την πιο κάτω διαδικασία:

Πατώντας το κουμπί 

μπορείς να εντοπίσεις τα κύματα P και S στο σεισμογράφημά σου. Για να εντοπίσεις για παράδειγμα το κύμα P πάτησε πάνω στο σεισμογράφημα το σημείο στο οποίο θεωρείς ότι αρχίζει το συγκεκριμένο κύμα (θα εμφανιστεί μια πράσινη κάθετη γραμμή) και έπειτα πάτησε το πιο κάτω κουμπί:

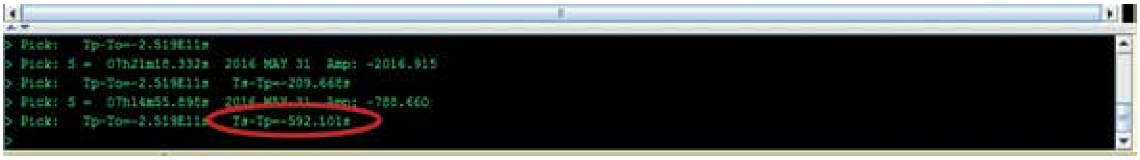
Έχεις τη δυνατότητα να μεγεθύνεις πάνω στο σεισμογράφημα περιστρέφοντας τον τροχό του ποντικιού.

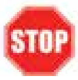
Ακολουθείς την ίδια διαδικασία και για το κύμα S.

Σε περίπτωση που κάνεις κάποιο λάθος, αν πατήσεις Del Prev διαγράφεται η τελευταία σου επιλογή και όταν πατήσεις Del All διαγράφονται όλες οι επιλογές.

Όταν τοποθετήσεις και τα δύο κύματα πάνω στο σεισμογράφημα, το πρόγραμμα σου εμφανίζει αυτόματα ένα κουτί όπου αναγράφεται η χρονική διαφορά (σε δευτερόλεπτα) μεταξύ των δύο κυμάτων.

Μπορείς να δεις επίσης τη χρονική διαφορά στο message window του λογισμικού:





3. Για να εντοπίσεις την απόσταση (dist.) του επίκεντρου από τον σεισμολογικό σταθμό (σε km) και να συμπληρώσεις τον πίνακα, ακολούθησε την πιο κάτω διαδικασία:

Παρατήρησε το σεισμογράφημα. Είναι ο σεισμός τοπικός ή μακρινός και γιατί;

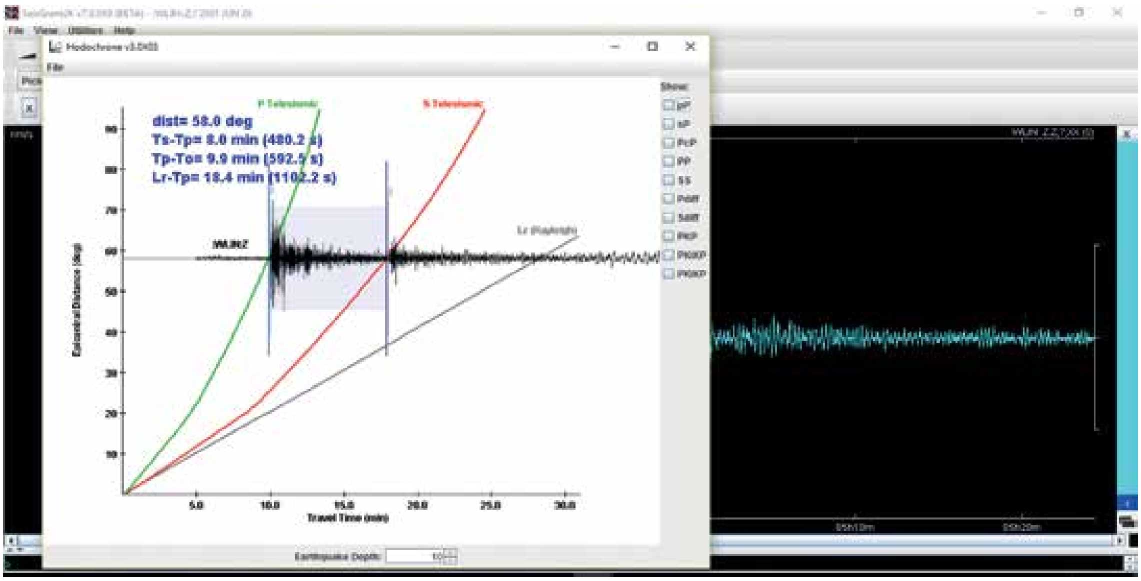
…………………………………………………………………………………………………

………………………………………………………………………………………………..

Αν ο σεισμός είναι τοπικός (απόσταση < 300km), τότε θα πρέπει να πατήσεις το κουμπί 

Αν ο σεισμός είναι μακρινός (απόσταση > 300km), τότε θα πρέπει να πατήσεις το κουμπί 

– Όταν πατήσεις ένα από τα δύο κουμπιά θα εμφανιστεί νέο παράθυρο με την κατάλληλη γραφική παράσταση. Στην εικόνα παρουσιάζεται η γραφική παράσταση για σεισμούς που βρίσκονται μακριά (απόσταση > 300km) από έναν σεισμολογικό σταθμό.



– Πάτησε το σεισμογράφημα και μετακίνησέ το πάνω στη γραφική παράσταση, ούτως ώστε:

- οι γραμμές των κυμάτων S και P που βρίσκονται πάνω στο σεισμογράφημα να ταιριάζουν με τις μπλε γραμμές που υπάρχουν στη γραφική παράσταση.
- η τιμή Ts-Tp (σε δευτερόλεπτα) να είναι όσον το δυνατόν πιο κοντά στην τιμή που βρήκατε εσείς όταν τοποθετήσατε τα κύματα S και P στο σεισμογράφημα (βλ. την τρίτη στήλη του πίνακα που συμπληρώνεις ή και το message window του λογισμικού).

! Προσοχή:

Τοπικός σεισμός: η διαφορά του χρόνου Ts-Tp θα εμφανιστεί σε δευτερόλεπτα (όπως δηλαδή εμφανίζεται και στο αρχικό κουτί όταν τοποθετείτε τα κύματα στο σεισμογράφημα).
Μακρινός σεισμός: η χρονική διαφορά εμφανίζεται σε λεπτά και στην παρένθεση εμφανίζεται σε δευτερόλεπτα.

– Αν δεν μπορείς να ταιριάξεις την τιμή Ts-Tp και τα κύματα με τις μπλε γραμμές, τότε η άλλη γραφική παράσταση ίσως είναι η κατάλληλη για το σεισμογράφημά σου.

Κλείσε το παράθυρο, επέλεξε την άλλη γραφική παράσταση ( ή ) και ακολούθησε ξανά τη διαδικασία.

– Γράψε στον πίνακά σου την απόσταση του επίκεντρου από τον σεισμολογικό σταθμό (αναγράφεται ως dist. στο παράθυρο που βρίσκεται η γραφική παράσταση) σε χιλιόμετρα (km).

Προσοχή:

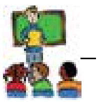
Τοπικός σεισμός: η απόσταση από το επίκεντρο του σεισμού (dist) θα εμφανιστεί σε χιλιόμετρα (km).
Μακρινός σεισμός: η απόσταση από το επίκεντρο του σεισμού (dist) θα εμφανιστεί σε μοίρες (deg).
1 μοίρα = ~111km *οπότε για να βρείτε την απόσταση του επίκεντρου του σεισμού σε χιλιόμετρα, θα πρέπει να πολλαπλασιάσετε την απόσταση σε μοίρες με 111 (π.χ. 58deg x 111= 6,438km).*

4. Για να παρουσιάσετε την απόσταση του σεισμολογικού σταθμού από τον σεισμό (με τη δημιουργία κύκλου) θα χρησιμοποιήσετε το **Google Earth Pro** (αν υπάρχει ήδη στον υπολογιστή σας δεν χρειάζεται σύνδεση στο διαδίκτυο για να λειτουργήσει):

- Άνοιξε το **Google Earth Pro.** Επέλεξε το κουμπί (add placemark), δώσε το όνομα του σταθμού στην επιλογή Name και γράψε το γεωγραφικό πλάτος και μήκος του σεισμολογικού σταθμού στα επόμενα κουτιά (Latitude και Longitude). Πάτησε OK.
- Επέλεξε από το μενού Tools/Ruler/Circle. Στην επιλογή Radius (ακτίνα) επέλεξε Kilometers (χιλιόμετρα). Βεβαιώσου ότι επιλογή Mouse Navigation είναι επιλεγμένη. Άφησε το παράθυρο ανοικτό.
- Πάτησε πάνω στον χάρτη την πινέζα που τοποθέτησες (δηλαδή την τοποθεσία του σεισμολογικού σταθμού) και χωρίς να έχεις πατημένο το ποντίκι μεγάλωσε όσο πρέπει τον κύκλο, ώστε στο κουτί που αναγράφεται η ακτίνα (Radius) να αναγραφεί η απόσταση του σεισμολογικού σταθμού από το επίκεντρο του σεισμού. Όταν αναγραφεί η σωστή απόσταση πάτησε το αριστερό πλήκτρο του ποντικιού σου και έπειτα πάτησε Save.
- Στο νέο παράθυρο που θα εμφανιστεί ονόμασε τον κύκλο σου (Name) με το όνομα του σεισμολογικού σταθμού και πάτησε OK.
- Κάθε φορά που τοποθετείς είτε πινέζα είτε κύκλο στον χάρτη, καταγράφεται στο αριστερό μενού κάτω από την επιλογή Places. Έτσι, αν έχεις κάνει κάποιο λάθος, μπορείς να το επιλέξεις και πατώντας δεξί κλικ και Delete να το διαγράψεις.

– Ακολούθησε την ίδια διαδικασία και για τα υπόλοιπα σεισμογραφήματα, συμπληρώνοντας πάντα τον πίνακά σου.

– Πού βρίσκεται το επίκεντρο του σεισμού; ……………………………………………………..............….



– Παρουσίασε και σύγκρινε τον τρόπο εργασίας σου και τα αποτελέσματά σου με αυτά των συμμαθητών σου.

Πατώντας File/Save Active as… μπορείς να αποθηκεύσεις το αρχείο σου. Συνήθως όταν αποθηκεύουμε σεισμογραφήματα η ονομασία που τους δίνεται είναι π.χ. 201606260424WLIN, δηλαδή: 2016 (χρονολογία) 06 (μήνας) 26 (ημέρα) 04 (ώρα) 24 (λεπτά) WLIN(ονομασία σεισμολογικού σταθμού).

"Measuring the Earthquakes in Turkey"

The lesson plan was developed according to Turkey's national curriculum

School level: Middle school

Grade, age of students: 8th grade, 13-14 years old

Approx. time needed: 135 minutes (3 Courses)

- Orientation phase: 15 minutes
- Conceptualization phase: 30 minutes
- Investigation phase: 45 minutes
- Conclusion: 45 minutes

Domain: Science

Sub-domain: Earthquake and Weather Cases / Earth and Universe

Classroom organization: Teams of 3-4 students

Students Gains:

- Students know the basic principles of earthquakes.
- Students measure earthquakes using data provided for them.

Science Process Skills:

- Students interpret data from seismogram.
- Students understand the pattern and relations from the findings obtained.

Means and materials:

For each student:

- Student Worksheet (you can find an indicative worksheet in the appendix)
- Seismogram paper

Activities description:

Orientation phase

If an earthquake occurred not a while ago, you can ask your students to mention experiences (what they felt, what and how they think it happened) or you can show a video or news broadcast about an earthquake event. After that you can ask the following questions: "Do you think earthquakes occur only in Turkey?" "Where do you think other earthquakes might occur and why?" "Why do you think we have so many earthquakes in Turkey?" ''Do you know how scientists can measure the earthquakes?" ''What kind of equipment and tools they use to determine the earthquakes?". You can have your students map their ideas about earthquakes and present some of them to the other students.

Conceptualization phase

In this phase, you can give information about tectonic plates, magnitude, intensity, earthquake focus, epicenter, faults, seismic waves and seismographs. You can have the students ask questions based on their observations, or if they are not familiar with the procedure, you can raise some of the questions. For example: "Where do earthquakes occur in relation to the tectonic plates?" "Why? (Observe the earth's layers)" "Do you think the morphology of the places that earthquakes occur (plates boundaries) is the same everywhere?" "What do you think are the differences/similarities and why?" You can have your students add their ideas on their concept map.

Investigation phase

Each team works cooperatively to use seismogram paper. Each student use a work sheet that is provided in the appendix (you should adjust the work sheet according to your students' needs and knowledge about the concept of the lesson and the processes of inquiry). Students label and describe types of seismic waves on the seismogram. Students also work like a seismologist. They observe and interpret data. Students determine the epicenter and magnitude of the earthquake.

During this phase, the teacher must have a guiding role. You can stop the teams when there is a need to discuss something altogether or you can add specific points to the working sheet so that students will know when they must stop and have a conversation with the whole class or call the teacher for a discussion within the team.

Conclusion phase

Students compare the data they collected during the previous phase with their concept map (initial ideas). They can add/delete/adjust (with a different color) what they have learnt and present it to the classroom (they can also do the same thing after they listen to all the teams or you can have a classroom concept map and teams can add to that).

Useful information for the teacher:

– **The lesson plan was developed according to inquiry – based learning (you can find more about it in the Intellectual Output 1 of the SSE project)**

– **If your students are not familiar with inquiry** you can follow a more structured type (e.g. give specific roles to the students of each team, have more structured activities during the investigation phase: provide them data, words they can use to explain certain things, examples, ways to organize their data)

– **If they are familiar with inquiry and /or the concept** you can choose a more open type of inquiry (e.g. they can organize their data in a form they choose is best)

The teachers can get further information about the earthquakes using the links below:
– http://earthquake.usgs.gov/learn/topics/
– http://www.usgs.gov/

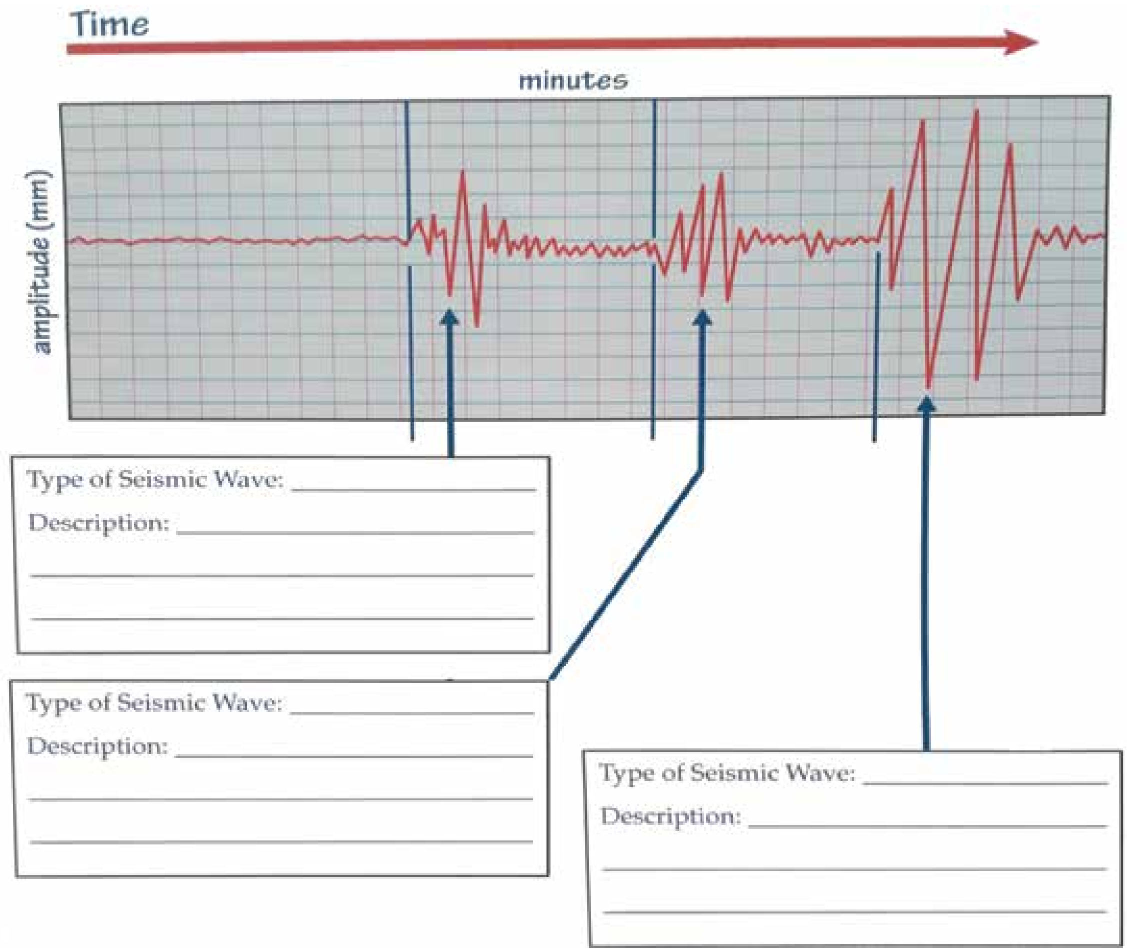
– http://scedc.caltech.edu/Module/module.html

– http://www.livescience.com/topics/earthquakes/

Appendix
Work sheet (investigation phase)
Seismogram paper

Pause and Review

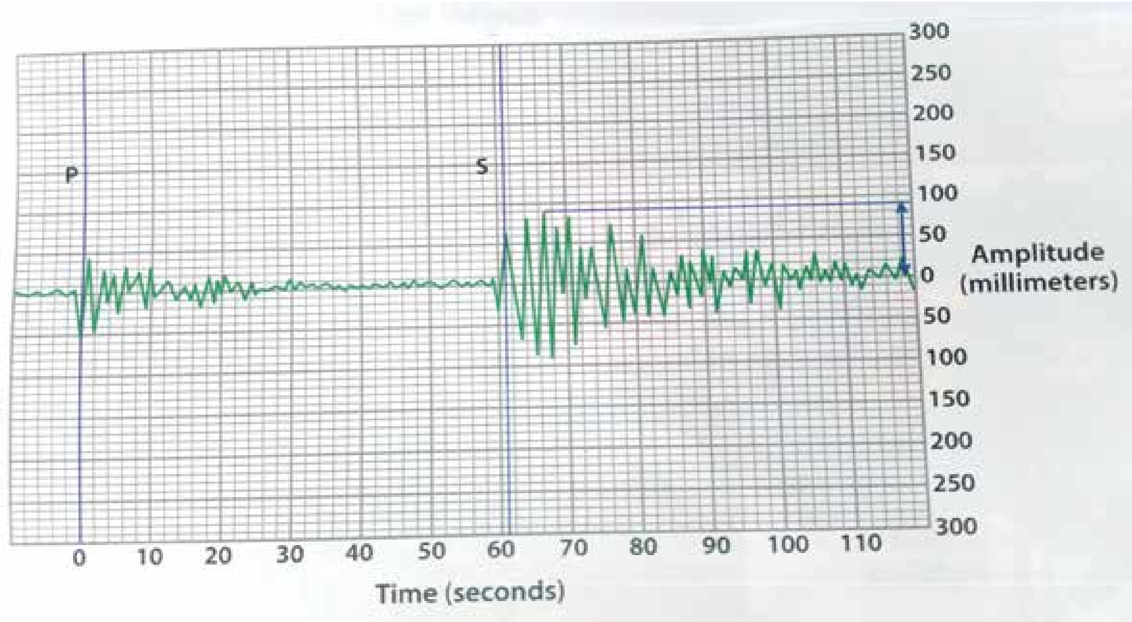
Label and describe the three types of seismic waves on this seismogram.



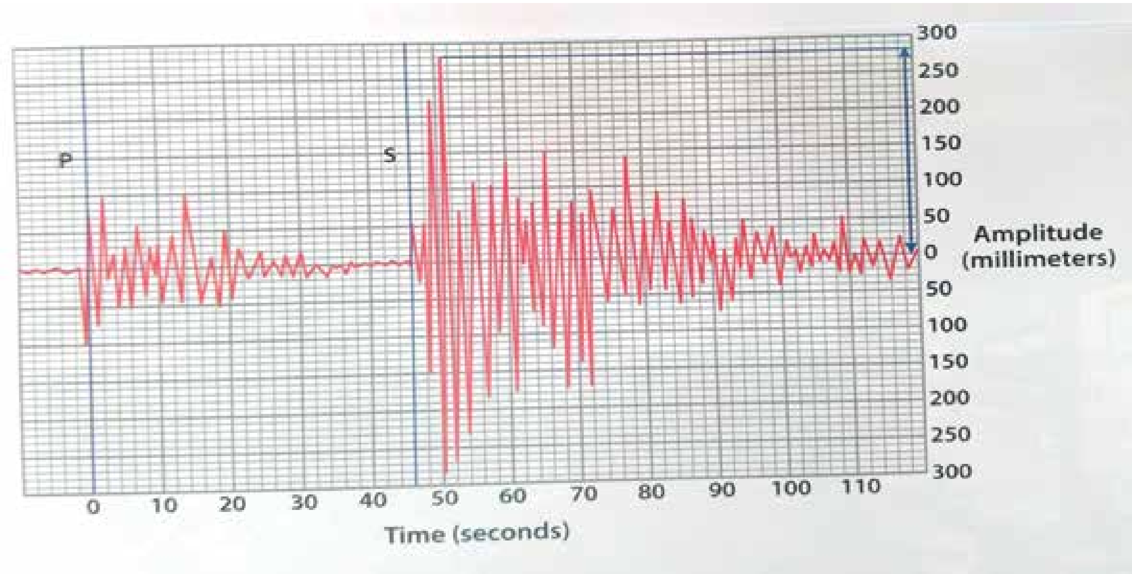
Observation & Data Collection

Study the seismograms. Determine the **S-P interval** for each seismogram. Add the data to the date table.

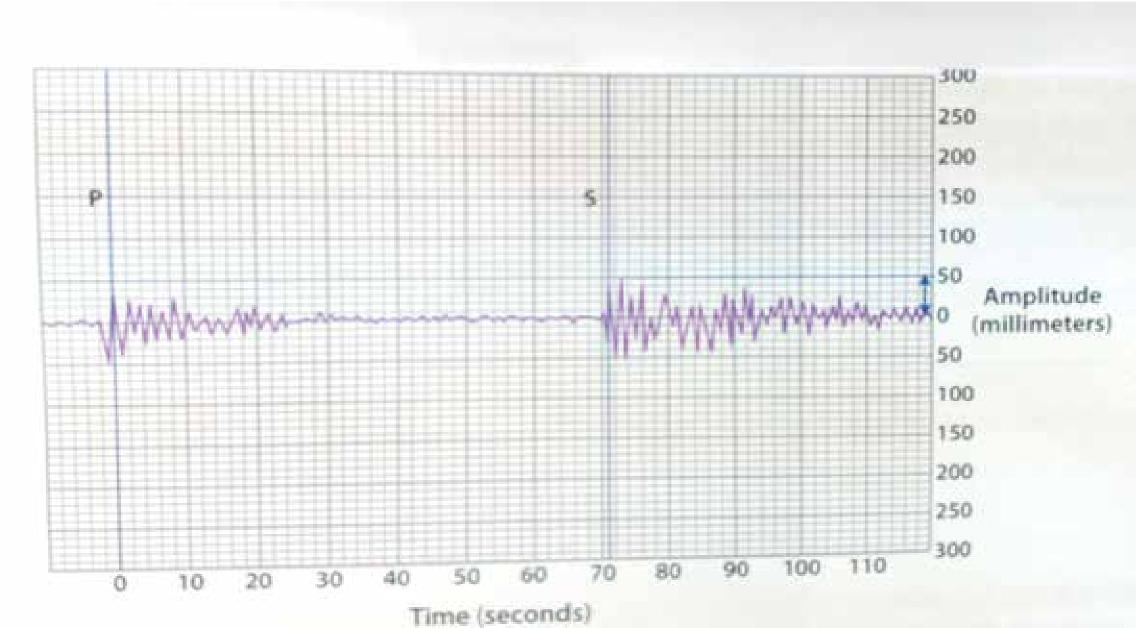
ESKISEHIR



IZMIR

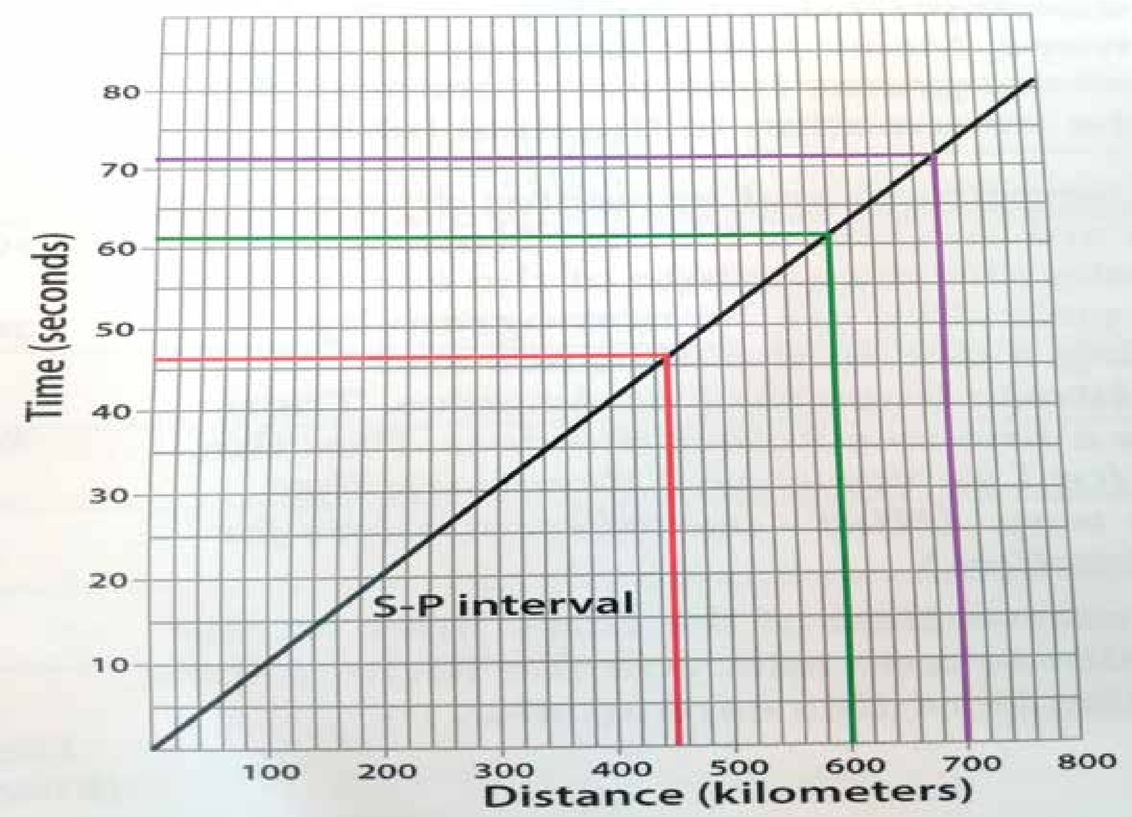


TRABZON



City	S-P interval (sec)	Epicenter distance (km)	Amplitude (mm)

Use the interval times and this graph to determine the **epicenter distance** for each location. Add the distance to the data table.



"Pangea Puzzle"

The lesson plan was developed according to Turkey's national curriculum

School Level: Middle School
Grade, age of students: 6th Grade
App. time needed: 2 Class hours
Domain: Science
Sub-domain: Geography
Classroom Organization: teams of 3-4 students
Conceptual Competencies:

- Students learn the structure of the Earth is made up of layers such as crust, mantle and core.
- The students can explain the properties of these layers.
- The students become aware of the existence of continental drift and the scientist who proposed it.
- The students realize Earthquakes are one of the results of continental drift and therefore Earth's structure.

Skill Competences:
Students use their logic and reasoning capabilities to define a model about the structure of the Earth as it once was 220 million years ago and support their ideas with clues from today's findings.
Means and Materials: World map, globe, Pangea puzzle, geological clue key
Activity Description:
Orientation Phase: The teacher begins by relaying the big question of the day: "How could it be possible to find same type of plants or same species of animals that lived 220 million years ago, in different parts of the Earth? (Before any real means of travelling across the continents.)

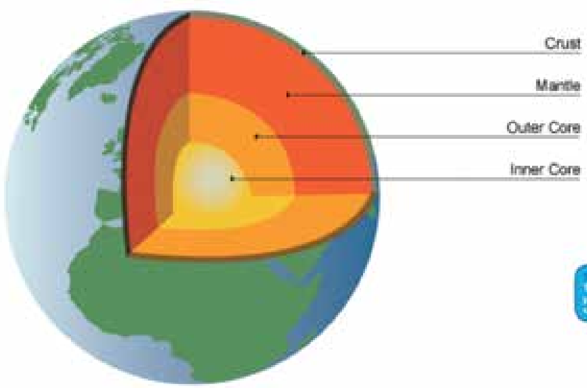
After volunteers tell what they think about this situation, the teacher can ask more questions like:
Do you think, do the continents float over the oceans?
Are the layers of the Earth the same thing as the continents on it? If not what is the difference?
If we could empty all the oceans, what would we find at the bottom?
Is Earth's crust a single solid shell?
What makes the tectonic plates move?
What do you think happens on the seafloor if two continents are shifting away from each other?

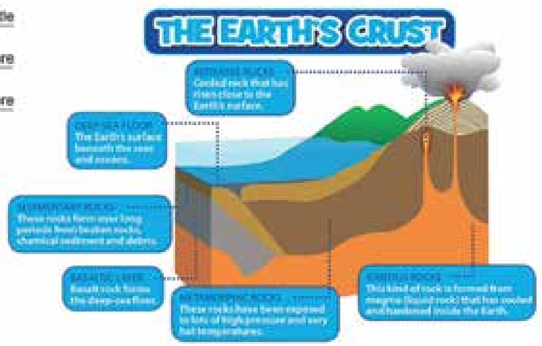
After listening to different answers, it would be a good idea for the class to form a mind-map about the key concepts they would like to learn in order to give a better answer to these questions.

(Evidence to support the existence of a giant super continent, scientist who suggested ideas about the reasons, details about the plate tectonics, the fact that earthquakes are a result of continental drift are relevant points)

Conceptualization Phase: Here the teacher can give more detailed information about the structure of the Earth and the eight major plates on the surface of the Earth that constantly keep moving atop the underlying mantle, a really thick layer of hot molten rock.

Major plates on the surface of the Earth Picture:

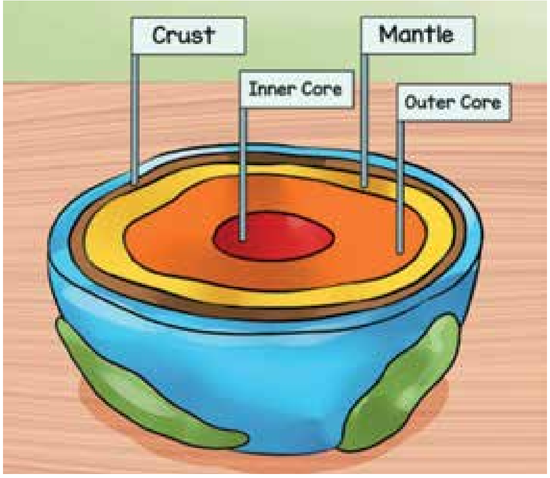




The class collectively should learn about continental drift, the reasons, the scientist who proposed it, the results and the evidence that supports the Pangea idea.

The structure of the Earth video: https://www.youtube.com/watch?v=eXiVGEEPQ6c
Plate tectonics Video: https://youtu.be/TcZtM-Fnyj1M
Plate tectonics Simulation: https://phet.colorado.edu/en/simulation/plate-tectonics
Continental Drift Infographic: http://www.kidsdiscover.com/infographics/infographic-continental-drift-theory-for-kids/
Continental Drift Info: http://www.geography4kids.com/files/earth_tectonics.html
http://www.nationalgeographic.org/encyclopedia/continental-drift/
http://www.geography4kids.com/files/earth_intro.html
Interactive Media about Earthquakes: http://earthquake.usgs.gov/learn/kids/

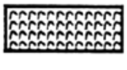
Investigation Phase: First we expect the students to make a model of the structure of the Earth using colorful playdough. Each layer will be represented with a corresponding color. The properties of the main layers should be emphasized and the fact that each layer may also be divided into sub-layers should be mentioned.



We expect the groups of students to use the Pangea puzzle pieces (North America, South America, Antarctica, Africa, Australia, India, Greenland and Eurasia) and the geological clue key (both may be found @ the Appendix) to form one giant super-continent known as Pangea. After they cut the continents and place them on a flat surface, they should discuss among themselves and decide which continent should be placed where and support their ideas using the geological clue key and the mind-map they did before. The teacher should remind the students that the landmasses they will be cutting out, represent the continents and some of the larger islands of the Earth the way scientists think they appeared 220 million years ago.

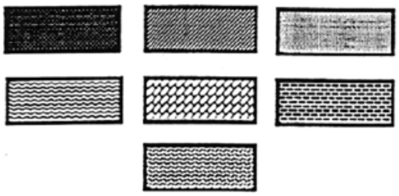
They should compare the physical shape of the continents with the given globe, see if the shapes will fit with each other.

The legends on the continents indicate:


Indicates mountains that were formed millions of years ago

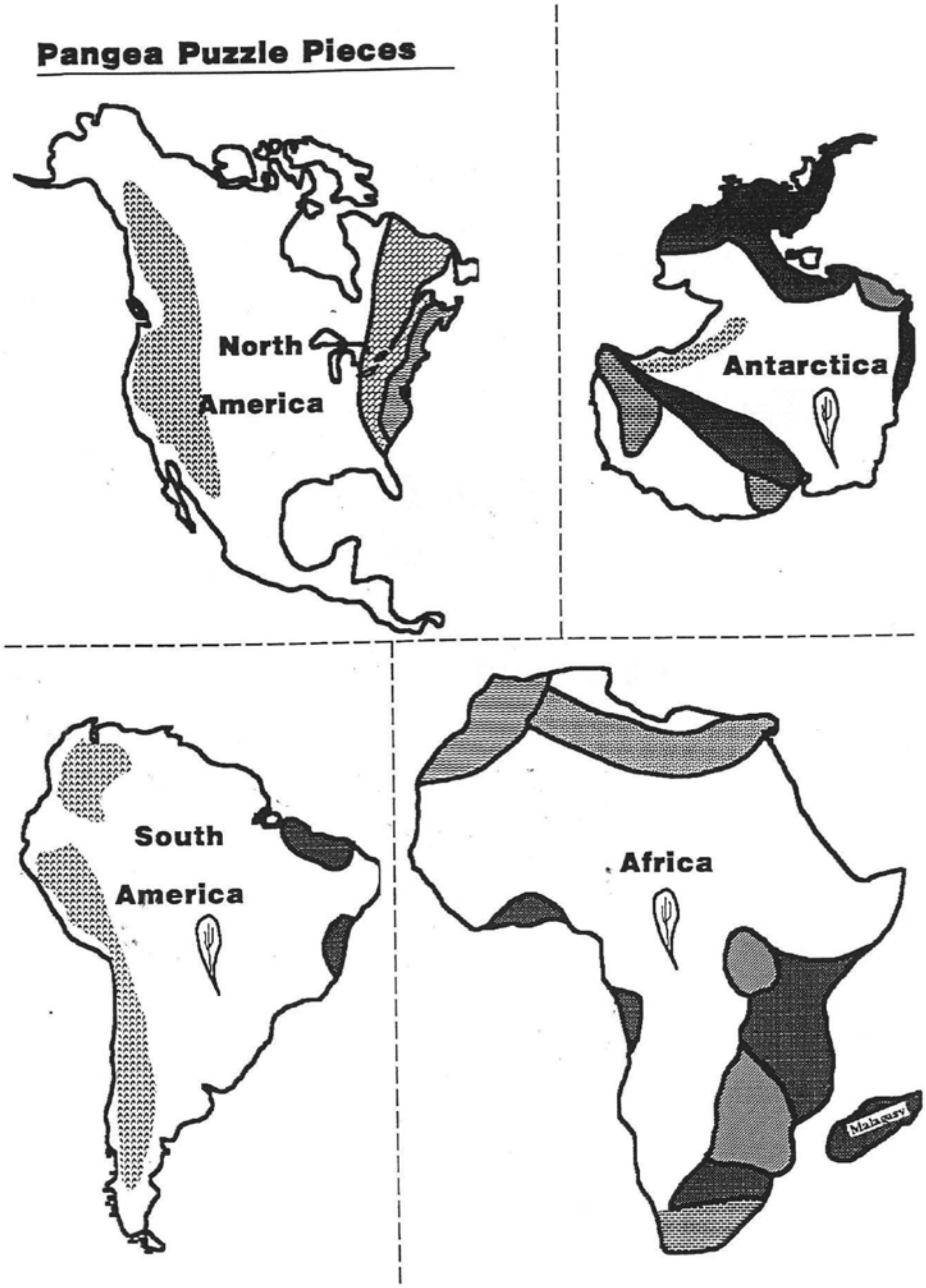

Leaf indicates continents where material left by glaciers coal and fossil plant land deposits are found.

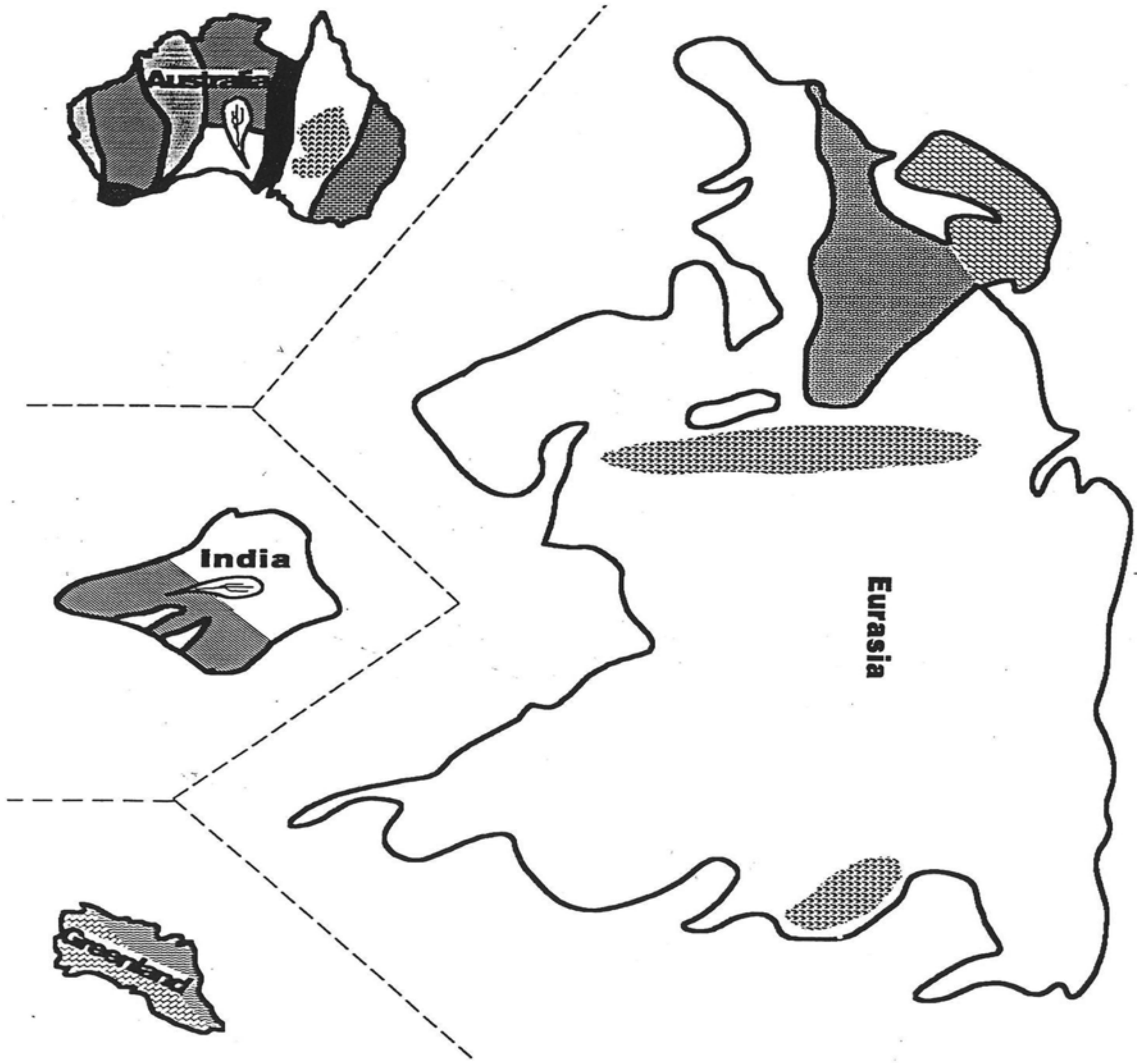
Kinds of rocks:



Conclusion Phase:
At the end of the lesson the students are encouraged to share their ideas and the underlying reasons behind them. If the students ask, which group found the right answer, the teacher should tell them we would need to invent a time machine and go back in time to be sure. We are just speculating regarding to the clues we have as the alternative is not a possibility yet.

Appendix:




Australia
India
Greenland
Eurasia

"Proper behaviour in an earthquake situation"

The lesson plan was developed according to the Bulgarian national curriculum

School level: Primary

Grade, age of students: 2nd grade, 8 years old

Approx. time needed: 85 minutes (approx. two school hours plus the break)

Domain: Environment

Sub-domain: Disaster protection

Classroom organization: Class, divided in several groups:

- students and teacher,
- rescue team – students, presumably boys (playing roles of firefighters, civil protection employees, policemen) - if possible another teacher or parents could join the exercise;
- doctors (emergency medical service) – another group of students, presumably girls

Concept competences:

Students acquire knowledge about:

- the nature and characteristics of an earthquake as an unexpected disaster with great speed and varying destructive power;
- the visible signs of the earthquake- sounds flutter to the ground, tearing of the earth's crust etc.;
- the dangers caused by the earthquake disaster and the possible negative consequences;
- rules of safe behaviour before, during and after an earthquake;
- precautions to reduce the risk of injury and infection;
- practical utilization of the Action Plan in an earthquake, acquainted with how to leave from the building safely and immediately after the first quake

Skill competences:

Various, depending on the role games and simulations:

- recognize earthquakes by their characteristics;
- describe possible damage due to an earthquake, which is characterized as a natural disaster;
- comply with the instructions of the teacher, guidance on radio, television; orientation to the safest places in the building (school, home) and safe passage to them;
- prepare basic necessities and valuables on leaving of the building;
- observe personal hygiene because of the danger of epidemics;
- comply with the guidelines for orderly leave from the classroom and the school immediately after the first earthquake at a particular location;
- assist in checking the students that are brought out or play roles of rescue team or doctors;
- know the main activities and instructions stipulated in the Action Plan in an earthquake

Means and materials:

For the teacher:

- internet connected laptop and multimedia projector
- PowerPoint presentation with photos from an earthquake origin and effects
- set of questions regarding the earthquake effects, negative consequences and safe behaviour

For each team:

Suitable signs made from colour tape and glue identifying the different roles of students (i.e. roles of firefighters, policemen, doctors)

> You can download suitable earthquake videos from YouTube such as:
> https://www.youtube.com/watch?v=he-SOBf-sOm8
> or
> https://www.youtube.com/watch?v=fq-2J6bLz2iQ

Activities description:

Orientation phase

The teacher explains to students the negative effect of earthquakes and shows some slides and videos. He/she explains to students what the visible signs of earthquakes are, after showing the YouTube videos and photos of possible negative consequences of earthquakes to the surrounding environment and buildings. The teacher explains why it is important to learn rules for safe behavior during earthquakes. Finally, he/she asks three students to draw out some of the questions and tell to the class what they remember from the presentation.

Conceptualization phase

The teacher starts discussing in detail safe behaviour techniques and precautions to reduce the risk of injury and infection after an earthquake situation. He/she draws an Action plan for evacuation and safe behaviour and choses roles for different students (i.e. firefighters, policemen, doctors). The students confirm that they have understood their roles and take the signs related to each role.

Investigation phase

The teacher announces the emergency (earthquake) and uses some of the surrounding objects to make bangs and noises typical for earthquake. Students rush under the desks with their heads bent between their knees and wrapped with hands. The teacher stands in the doorway, where he/she can observe and guide students and react when necessary. These final moments of the first class coincide with the school break. After the first "quake"students get out of the classroom to the school yard. Just before leaving the room, the teacher simulates an incident situation and asks few of the "firefighters" to help drag out of the "ruins" 2-3 randomly chosen students with "injuries".

During the break, the whole class goes to a safe distance from the building and the teacher guides the "doctors" how to provide first aid to the earthquake "victims". For authenticity purposes, he/she may use red pencil or colored paper to illustrate different injuries.

Conclusion phase

The class return to the room and the teacher makes complete analysis of the whole game exercise and gives recommendations and advice to students. He/she could use the remaining time to split the class into groups of two and give them questions to ask and answer to each other. He/she moves around the groups, listens to the dialogues and corrects the answers if necessary.

Useful information for the teacher:

- **The lesson plan was developed according to inquiry – based learning (you can find more about it in the Intellectual Output 1 of the SSE project)**
- **The teacher could save some time by allocating students roles (i.e. firefighters, civil protection employees, policemen etc.) in advance and prepare the necessary materials**
- **The teacher may use the time before the class to check the laptop, the multimedia and the internet connection in order not to lose precious time during the class**
- **The teacher may use the first few minutes of the class to ask how many students know what an earthquake is in order to adapt the presentation to the level of the students**
- **The teacher could orient his/her questions directly to the premade slides so that each slide (illustrated with some pictures/photos) covers 2 - 3 questions**
- **During the "earthquake" the teacher could make some digital photos of the students' behavior with his/her smartphone and use them to illustrate his/her analysis after the end of the game**
- **The teacher could ask the students some reasonable questions like "What is according to you the safe distance from a building once you get out of it during an earthquake situation?" or "Why do you think is dangerous to leave switched on electricity and heating devices in an earthquake situation?" in order to provoke their casual connection thinking**
- **Due to the relatively long exercise (two school hours) and the distribution of students into two groups, it is recommended to find another teacher or parent for support and assistance during the role game situation.**
- **The teacher could use the questions and materials in several different classes enriching them during the interaction with students and thus refining the quality of the lesson plan**

Appendix
Some preliminary slides and related questions

1. What are the basic characteristics of an earthquake? How do we recognise it?
Leave the students to explain with their own wording (visual signs, noises, feelings)

a. Explain the difference between the two pictures – do they both show natural disasters?

b. What are the dangers caused by an earthquake disaster and the possible negative consequences? Explain how you came up with this decision.

c. Why people should not panic during an earthquake situation? Please explain.

2. What do you think is the safest behaviour during an earthquake? Explain how you should handle the situation during the different earthquake stages.

a. What is wrong with that reaction to an earthquake?

b. How far you should go from the neighbouring buildings after the first quake? Why?

c. What are the biggest risks after the earthquake situation? Please explain.

3. What should be your Action plan in an earthquake situation? Please enumerate your activities accordingly.

a. What belongings you should take first?

b. What are the authorities? Whose advice must we follow in an earthquake situation?

c. Please prepare an earthquake Action plan and keep it in an appropriate place - homework for students.

Based on the experience you have gained during this game:

*Ask your parents which are the biggest earthquakes in the country they remember.

* Ask your classmates after a couple of weeks what they remember as possible negative consequences after an earthquake.

*Prepare an Action Plan for an earthquake situation.

"How to find the epicentre of an earthquake using modern information technology"

The lesson plan was developed according to the Bulgarian national curriculum

School level: Secondary

Grade, age of students: 9th grade, 15 years old

Approx. time needed: 85 minutes (approx. two school hours plus the break)

Domain: Geography, Physics

Sub-domain: Disaster protection

Classroom organization: A joint lesson in Geography and Physics supported by both teachers:

- students and teachers in Geography and Physics,

Concept competences:

Students acquire knowledge about:

- the nature and characteristics of S-waves and P-waves during earthquake and their effect on the environment and population;
- the availability of relevant information resources regarding the earthquake;
- the principle and usage of seismometers;
- the availability of relevant resources on the internet and how to use them in real life situations
- the methodology for calculating the epicentre of an earthquake using publicly available software tools

Skill competences:

Various, depending on the role games and simulations:

- recognize S-waves and P-waves by their characteristics;
- knowledge how to install, calibrate and use simple seismometer;
- knowledge how to analyse seismograms and define the distance between the seismic station and the epicentre of an earthquake;
- reliable information where to find relevant seismic data and relevant software for analyses (i.e. jAmaSeis, .sac files etc.) of earthquakes
- knowledge how to compare the working results with official seismological data sources

Means and materials:

For the teacher:

- internet connected laptop and multimedia projector
- A TC1 Seismometer for demonstrating assembling, calibration and usage
- relevant earthquake data (i.e. sac files from at least three different seismic stations), for the purposes of locating the epicentre

For the class:

If there is no way to have a personal computer for each student, then all the necessary resources must be downloaded to the teacher's laptop. In all situations students must be aware of useful web resources that could be used during the classes or for self-preparation.

In case there is some extra time left during the classes, a short live conference could be organised with SSE project partners, using suitable Software platform – for instance the Virtual room of the Ministry of Education and Science based on Adobe Connect platform.

You can download suitable software and information resources as follows: jAmaSeis Education Software- http://www.iris.edu/hq/jamaseis/

Information about S and P-waves (educational video) http://resursi.e-edu.bg/content/ph2/runtime/rtleo/scorm-flo.html?sco=..%2F..%2Fcontent%2Fuc_p5_1082.flo&width=788&height=553&recording=true

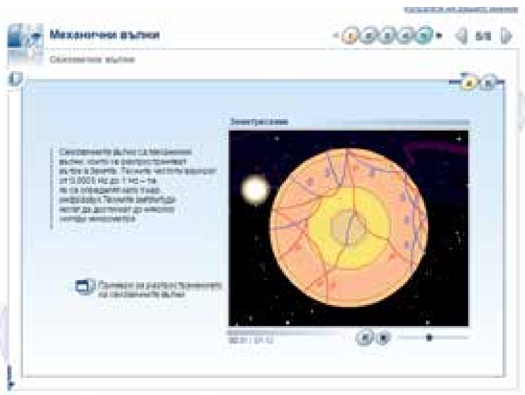
Useful resources:

European Mediterranean Seismological Center - http://www.emsc-csem.org/Earthquake/info.php

Schools Study Earthquakes Project - http://sse-project.eu/

Activities description:

Orientation phase

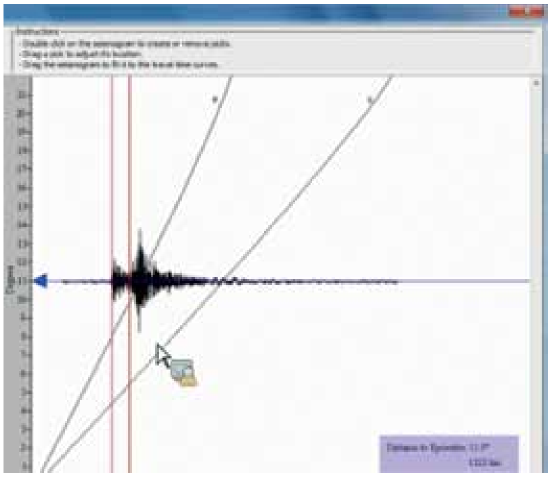


The teacher explains to students what seismic waves are, what seismogram is and how we could make the difference between S and P waves. The explanation is supported by an educational video (resource above) and if possible some YouTube clips of a real earthquake helping students better understand the difference and the possible effect of both waves. During the course all parameters of an earthquake are explained and it is stressed on the importance of the real distance between the location of the observer (seismic station) and the real earthquake epicenter/hypocenter.

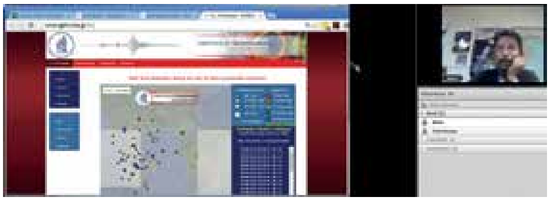
Conceptualization phase

The teacher shows student a real TC1 seismometer, explains its functionality and the way its data is recorded using jAmaSeis software. The class is led through the whole process of assembling, tuning and installation, including overview of basic software parameters. Specific attention is dedicated to important details like synchronising the time of the respective workstation The teacher mentions few important seismological resources and also could demonstrate how the class could use network data earthquake resources (.sac files) gathered during the Schools Study Earthquake Project (http://sse-project.eu/?m=7). The conceptualisation phase ends with understanding how to find a seismogram from a specific date/hour and loading it in jAmaSeis.

Investigation phase



Once a seismogram is loaded in the software (jAmaSeis) the teacher explains how to select the frames of the potential investigation object (i.e. earthquake) and how to adjust S and P curves, so that the real distance between the earthquake epicentre and the seismic station is estimated. It is important to draw students' attention on the fact that distance alone is not enough in order to find the epicentre because one seismogram gives just a circle. In order to find the exact epicentre location triangulation is needed – i.e. at least three different seismograms from one and the same event need to be loaded and their crossing of circles points the epicentre location. It is recommended some specific events (i.e. stronger or closer earthquakes) to be chosen by the teachers upfront and during the investigation phase to explain students their specifics in order to make the material more close and engaging. What will be really interesting is to compare the experimental results with some well know earthquake resources – like http://www.emsc-csem.org/Earthquake/info.php for example in order to compare the test seismograms with the most precise scientific instruments. In this case even a live web conference with some of the SSE partners could be organized and short online discussion conducted.



Conclusion phase

Teachers conclude the session making complete analysis of the lessons learned and main topics discussed – seismic waves and their types, epicentre and hypocentre, assembling and setting up a real seismometer, finding and using relevant software, measuring distance to the epicentre and triangulation using several sources, allocating important seismic resources and comparing the official data with the experimental results. They share with the students all useful links and materials and leave some time for questioning. At the end they give relevant homework to students and close the classes.

Useful information for the teachers:

- **The lesson plan was developed according to inquiry – based learning (you can find more about it in the Intellectual Output 1 of the SSE project)**
- **The collaboration of teachers in Geography and Physics and the interdisciplinary nature of the proposed lessons is a serious challenge everyone but with suitable preparation could be very helpful for the learning process and raising students' interest towards the material**
- **The teachers should use the time before the class to check the laptop, the multimedia and the internet connection in order not to lose precious time during the class. Most of the computer settings (for instance jAmaSeis parameters) could be prepared up-front and just commented during the learning session**
- **Both teachers (Physics and Geography) should find relevant ways to make a smooth transition from other topics to the earthquakes and seismic waves – for instance the Physics teachers could discuss the more general topics for mechanical waves, while the teacher in Geography could make reference to tectonic plates and their movement**
- **It would be nice to encourage students to think scientifically and to believe that measuring earthquake parameters is not so difficult once you have the understanding about general processes and principles and simple equipment like TC1 could do great job for education purposes**
- **It is important to give students suitable homework so that they could repeat at home conditions some of the experiments they have conducted at school (like installing jAmaSeis), picking relevant seismograms and calculating the epicenter**
- **Due to the relatively long exercise (two school hours) it is good to have both teachers on site during the whole session**
- **The teacher could use the questions and materials in several different classes enriching them during the interaction with students and thus refining the quality of the lesson plan**

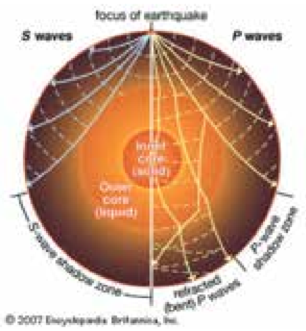
Appendix

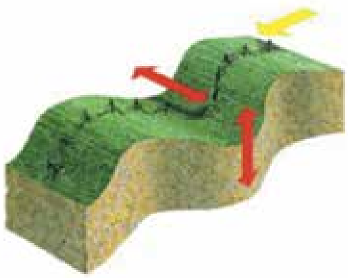
Some supporting questions and ideas for homework

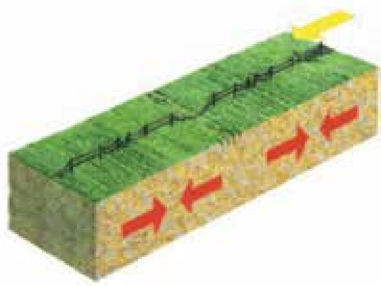
1. What are the basic characteristics of an earthquake? How do we recognise it?

Leave the students to explain with their own wording (visual signs, noises, feelings)

a. Explain the difference between the S and P-waves and explain which are more destroying and why?







b. Explain the principle of seismometer and why it is important to calibrate it and synchronise the timing of the software clock.

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c. Why it is not possible to calculate the distance to an earthquake epicentre using just one seismic station and how works the triangulation in classroom conditions

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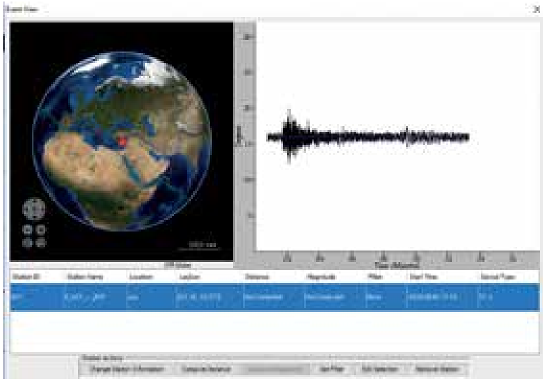
2. Do you know how to read seismograms and how to use seismic software.

a. Please try to mark the beginning of S and P waves on the following diagram and give a simple explanation why you think so



b. Pick three seismograms from different earth stations for one and the same earthquake and try to find where is the epicentre – explain why it is important to synchronise the clocks of all earth stations

c. Check with the website of the European Mediterranean Seismological Centre (http://www.emsc-csem.org) whether your measurements correlate to any known event and how close you were in finding the epicentre

Explain if there is a difference what could be the possible reasons

3. Try to write as a homework what will be your behaviour if you are supposed to explain in details about an earthquake to your local community – like where the earthquake happened and what are the important things they should know – enumerate all steps below

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____

____

a. Which are the websites you'll visit for a relevant information

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b. Why you trust these sources – your community should be aware if they deserve the trust and why?

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c. If there are small kids in the community try to explain to them as much as possible for the seismic waves and their effect

____

____

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Based on the experience you have gained during this lesson:

* Try to find biggest earthquakes worldwide for the last year and find at least one relevant seismogram.
w

* Pick one earthquake event in Europe and use the SSE project website to find suitable seismograms from it based on the date/time.

* Using triangulation try to compare the calculated epicentre with the real scientific data

"How to locate the epicenter of an earthquake"

The lesson plan was developed according to the Italian national curriculum

School level: high school

Grade, age of students: from 8th to 13th grade, 13-18 years old

Approx. time needed: 90 minutes

Domain: Natural sciences

Sub-domain: Geology and geophysics

Classroom organization: teams of 2- 3

Concept competences:

- Explain how geophysicists individuate the location of the epicenter of an earthquake

(Indicative) Skill competences:

- Interpret data gathered from the analysis of a seismogram;
- Carry out a true scientific experiment using real data by mean of ICTs

Means and materials:

For each student:

- work sheets suitable to collect data

For each team:

- computer
- software:
    - Seisgram2K
- Files of seismic recordings
    - Google Earth Pro:

You can download Google Earth Pro from: https://www.google.it/earth/download/gep/agree.html

You can download Seisgram2K from: http://www.edusismo.org/liste_meds.php or http://www.sismoscholar.it/sofware-per-analisi-dati

You can get seismic recordings from: http://www.orfeus-eu.org/ and in particular from http://www.orfeus-eu.org/eida/eida.html

Activities description:

Orientation phase

This educational activity concerns the analysis of seismograms and in particular the localization of the epicentre of an earthquake starting from the analysis of the recordings gathered by seismic stations seated all around the world.

The lesson can be started by showing to students some pictures of seismograms related to earthquakes of different magnitudes and triggered at different depth, as well as recorded by seismographs seated at different distances from the epicentres. The interest will be focused on some shapes characterizing the recordings and allowing us to grasp some features of an event like the hypocentre depth and the distance between the epicentre and the seismic station.

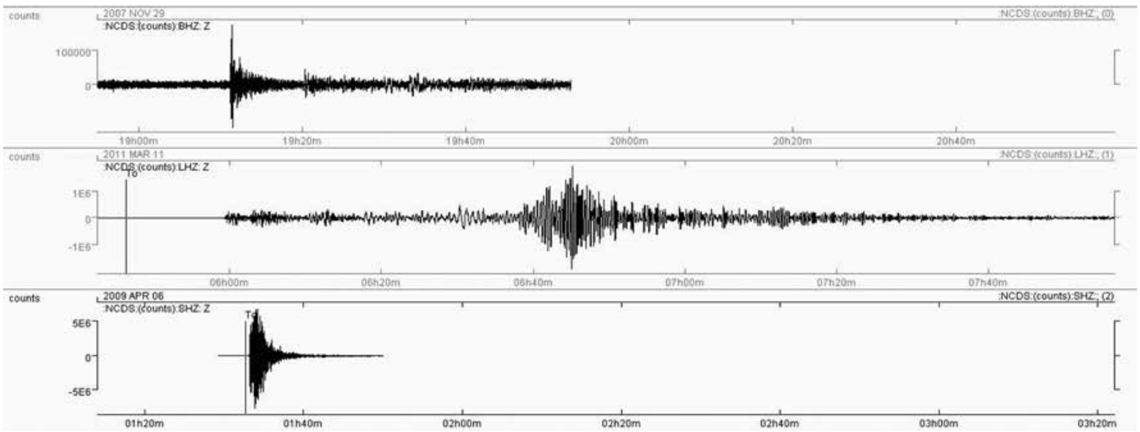


Fig 1.The waveforms of three different earthquakes recorded by the same seismic station (PDM broadband seismometer seated in Città della Scienza, Naples, Italy). Above: waveform of an earthquake occurred in Winward, Martinica, on November 29th 2007, M 7,3, depth 173 km. Centre: the earthquakes occurred in Honshu, Japan, on March 11th 2011, M 8,8, depth around 20 km. Below: earthquake occurred in L'Aquila, central Italy, on April 6th 2009, M 5,9, depth around 10 km.

Conceptualization phase

The localization of the epicentre of an earthquake is carried out by means of the so called three circles method (triangulation). Once the distances between at least three seismic stations and the epicentre have been calculated, starting from the differences in time of the first arrivals of the P and S waves to the station, three circles, whose diameter is proportional to the related epicentral distances, are traced on a topographic map. The epicentre is located in the point where all three circles intersect.

Once the students have grasped the idea that the distance between the epicentre of an earthquake and a seismic station can be calculated starting from the related seismograph, the teacher will train them by the use of Google Earth Pro. This application offers the function “circle” on the menu “ruler” from the toolbar. The function “circle” allows drawing on a world map circles whose radiuses are variable. So, the students can be invited first to set three mark points on the earth’s surface and then three circles having the mark points as centres. Therefore, the students will verify that the three circles can reciprocally touch each other in just one point, depending on the chosen radiuses.

Investigation phase

To locate the epicentre of an earthquake, usually researchers apply this method recurring to recordings gathered by seismic stations seated close to the epicentre to get a more accurate localization. Moreover, in these contexts the localization doesn’t feature just the calculation of the difference in time between the arrivals of P and S waves and the solving of an equation, but it also implies complicated corrections depending on the depth where the events has been triggered, the local geology and therefore the mechanical features of the rocks passed through by the waves. These factors should be well known by the researchers studying an earthquake.

Instead our activity entails the use of recordings gathered by seismic stations seated very far (thousands of kilometres) from the epicentre. In this way, the effect of local geology as well as the occurring errors in distance is negligible if compared with the distances between the epicentre and the seismic stations. The use of such kind of software application like Google Earth Pro allows us to mark circles having as radiuses directly the great circle route due to the round shape of the Earth.

Students will be divided into groups of two or three people. Each group will be equipped with a PC.

The teacher will have previously installed on each PC the software and files necessary to localise the epicentre of an earthquake:
• Seisgram2K to analyze the seismograms;
• Google Earth Pro to localize the epicentre.

On the desktop of each PC each group will find a directory containing the seismogram of a significant earthquake recorded by a seismic station chosen by the teacher and gathered by the EIDA database of the Orfeus web site (145.23.252.222/eida/webdc3/), and a file giving some information about the seismic station such as geographical coordinates and altitude. Each directory can be named with the acronyms officially identifying the seismic station.

For example, in this script it has been chosen an earthquake occurred on October 26th 2015 in the north-eastern Afghanistan. This earthquake has been chosen because of its high Magnitude (7.5) and therefore seismographs all around the world recorded it and because it has been triggered very deep (over 200 km) and therefore the first arrivals of P and S waves are clearly visible on the waveforms.

Three seismic stations have been chosen (table 1) seated respectively in southern Italy[1], Japan and in Maldives’ islands. Students compare the data they

1. The EIDA database of Orfeus web site makes available seismographs recorded in every country of the world so teachers and educators can choose for a seismograph recorded in their own countries.

Seismic station	Network	Location	Latitude	Longitude	Altitude (m s.l.m.)
KAAM	G (Deutsch-es GeoFor-schungsZen-trum)	Madaveli, Mal-dives’	0,4926 N	72,9949 E	0
INU	GE (Geoscope – IPGP)	Inuyama, Japan	35,35 N	137,029 E	132
LIO3	IX (AMRA)	Lioni (AV), Italy	40.8969002 N	15.1803999 E	737

Table 1. Acronyms, geographical coordinates and other information about the seismic stations.

collected during the previous phase with their concept map (initial ideas). They can add/delete/adjust (with a different color) what they have learnt and present it to the classroom (they can also do the same thing after they listen to all the teams or you can have a classroom concept map and teams can add to that). The stations have been chosen because of their position and their distance which is relative to the epicentre of the earthquake. For such kind of earthquakes an effective distance could be in a range between 2000 and 6000 km.

Then, the teacher will ask the student to open the file of the seismographs they got by using Seisgram2k. On each of the three recordings the students should easily recognise the first arrivals of P and S waves considering the pictures of seismograms showed by the teacher at the very beginning of the lesson. So, the teacher will ask the students to determinate the difference of time between the first arrival of P and S waves by using the available function “pick”. Once they will have gathered this difference in time they will be invited to determinate the distance between their “own” station and the epicentre first by using the printed table of Jeffrey & Bullen (see figure 3) and a ruler. Then they will do the same exploiting the function “Hodrochrone-Tele” of Seisgram2K [2].

In both cases the distance they will get will be expressed in degrees (°). The value of a degree on Earth surface is around 111 km, so the students must multiply the gathered value in degree by 111 km to get the distance in kilometres.

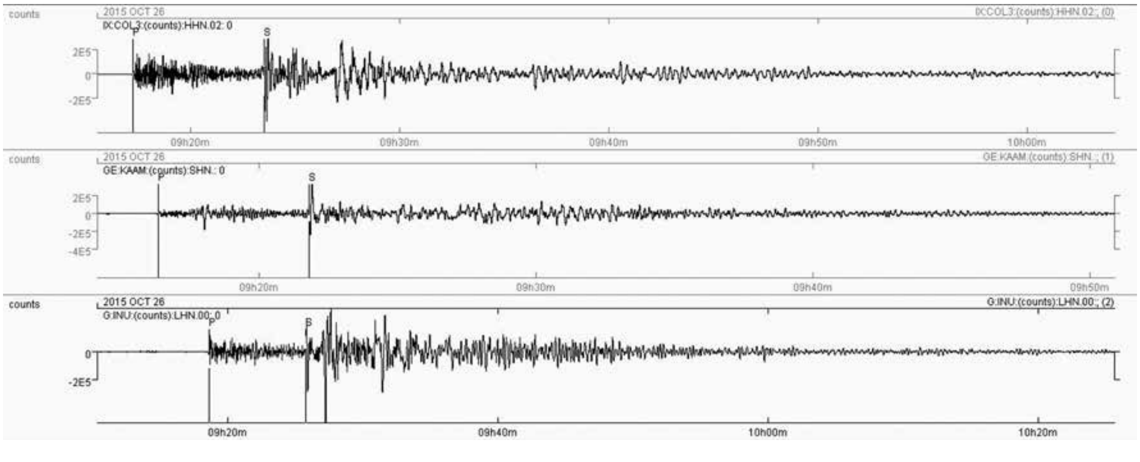


Fig 2. the seismograms of the event recorded by the N-S components respectively of the seismic station LIO3 (top), KAAM (centre) and INU (below). The vertical lines highlight the first arrivals of P and S waves on each recording.

2. The hodochrone changes the shape of its trend in relationship with the hypocentral depth. The students couldn’t previously know the depth but the teacher could remind them the pictures showed at the beginning of the lesson and suggest setting up a depth of 150 - 200 km.

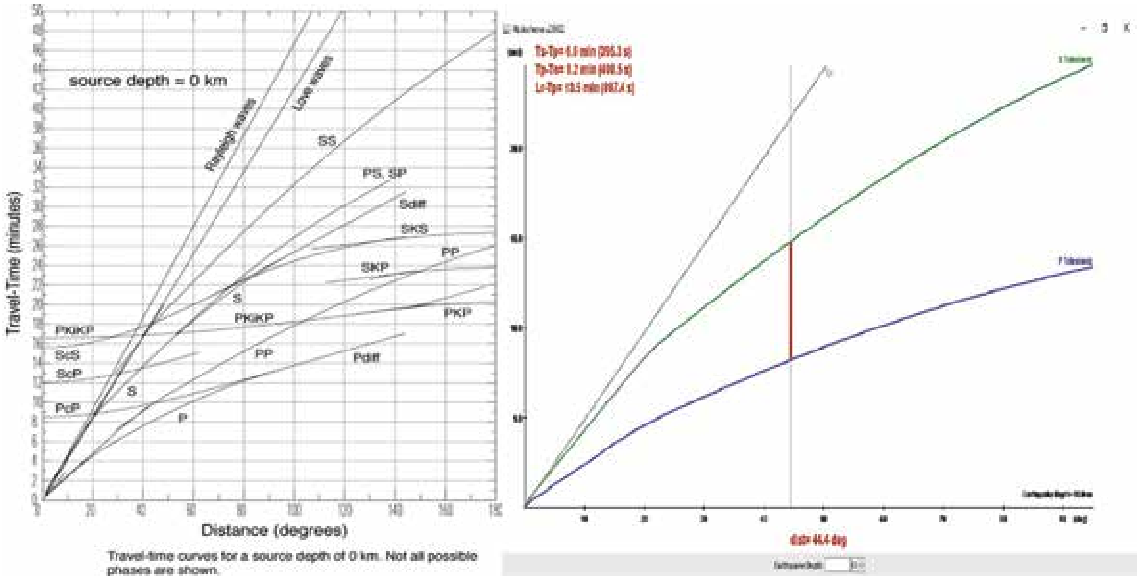


Fig 3. the table of Jeffrey & Bullen (left) reports on y-axis the arrival times of different kinds of seismic waves depending on the distance from the epicentre (x-axis) expressed in degrees (°). Notice the trend of the two curves on the window Hodochrone-Tele of Seisgram2K (right) is the same of the ones for P and S waves on the table of Jeffrey & Bullen.

Conclusion phase

Once each group has calculated the distance between their own station and the epicentre, they will share this information with the geographical coordinates of their own stations. To make the activity more interactive, the groups will be named by the teacher with the names of the seismic station they are representing. So during the sharing of information the groups will interact as real international groups of researchers.

Seismic station	T_S - T_P (s)	Distance (°)	Distance (km)
INU	433,6	52,9°	5872
KAAM	325,7	36,2°	4018
LIO3	379,9	44,4°	4928

Table2. epicentral distances of the three seismic stations determined by means of the window "Hodochrone-Tele" of Seisgram2K knowing the difference in time of the first arrivals of P and S waves (TS – TP). Considering the shape of the seismograms, in the window it was set up a depth of 200 km.

The location of the epicentre will be determined in a graphical way using Google Earth Pro. First, each group will place on the 3D World map some "placemarks" corresponding to the seismic stations whose geographical coordinates will be already known by the students.

Once the placemarks are placed, by using the function "circle" of the menu "ruler" of the toolbar, they will draw three circles having the centres corresponding to the seismic stations placemarks and radiuses scaled to the epicentral distances. The epicentre is located in the point where all three circles intersect. As already said, the radiuses of the circles traced on Google Earth Pro are not conceived as straight lines but as circle routes on round surfaces, so the method can work also for distances thousands of kilometres long.

As a feedback to evaluate if the procedure was performed right, the teacher will show to the students the web page related to the earthquake in question on the Significant Earthquakes Archive of USGS (http://earthquake.usgs.gov/earth-

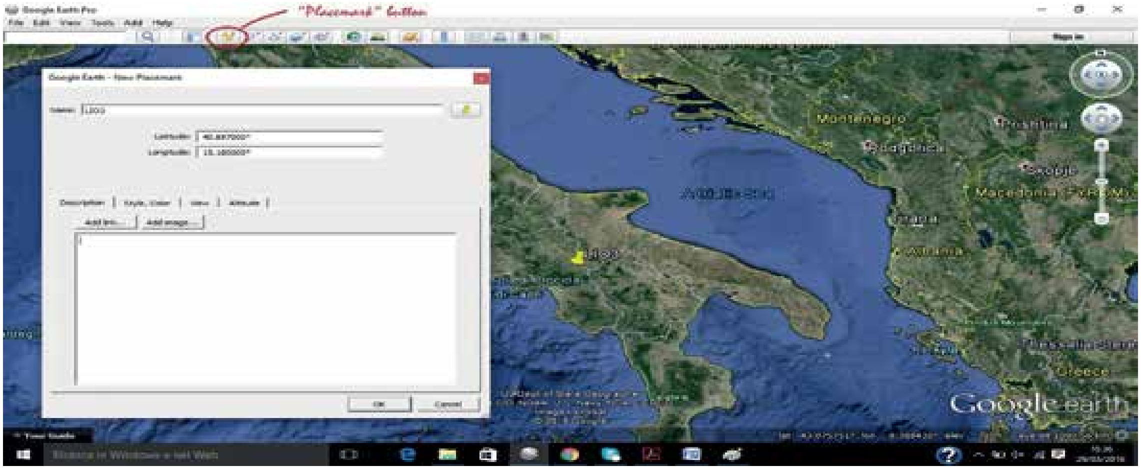


Fig 4. The "Placemark" button, its dialogue window and the placemark of LIO3 seismic station

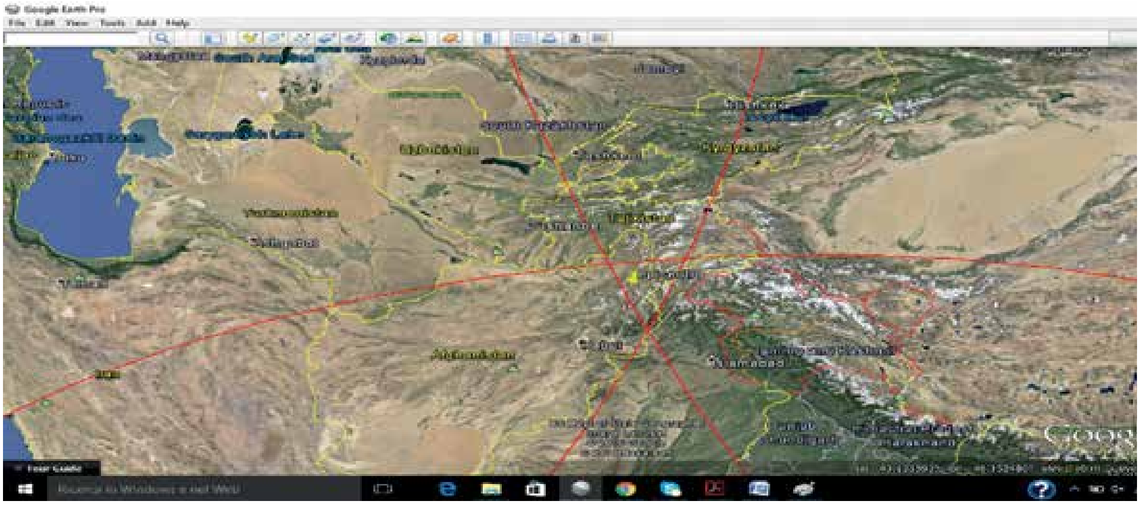


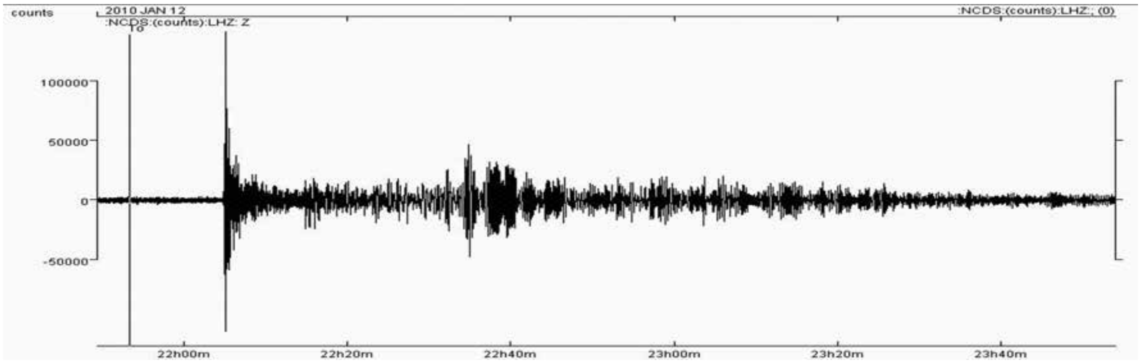
Fig 5. the placemark showing the epicentre of the earthquake seated inside the spherical triangle made by the intersection of the three circles. The geographical coordinates the have been provided by USGS bulletin.

quakes/browse/significant.php) where there is a researches report of the geographical coordinates of the event. So, the students will put on the Wold map a new placemark having these coordinates to verify if they are situated into the area described by the intersected circles.

APPENDIX

All the activities proposed can be carried out by the students by using just their PCs. Work sheets reporting some questions and exercises like the ones below can be provided to each student to allow better training and more confidence with the topics proposed during the activity.

Look the seismogram below. Remember the ones the teacher has showed you at the beginning of the lesson and try to grasp the features of the earthquake that produced it.



First consider its duration. Where do you think it has been recorded?

☐ Near its epicentre ☐ Far from its epicentre

Do you think its magnitude is:

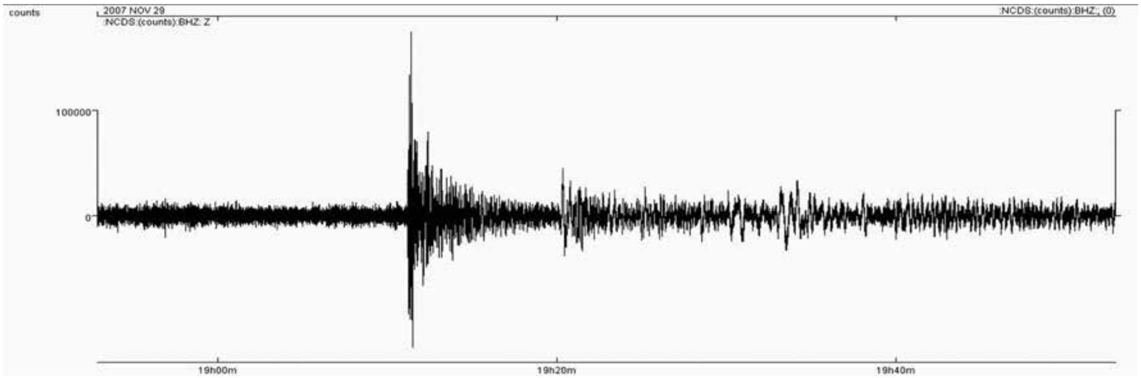
☐ Low ☐ High

Now try to individuate the first arrivals of P and S waves and indicate them with a pencil. Then individuate the surface waves and draw a circle around them.

Starting from these features of the recording, do you think the hypocentre of this earthquake is:

☐ Deep ☐ Surface ☐ I don't know

Now look this second seismogram below try to grasp the features of the earthquake that produced it.



First consider its duration. Where do you think it has been recorded?

☐ Near its epicentre ☐ Far from its epicentre

Do you think its Magnitude is:

☐ Low ☐ High

Now try to individuate the first arrivals of P and S waves and indicate them with a pencil. Then individuate the surface waves and draw a circle around them.
Starting from these features of the recording, do you think the hypocentre of this earthquake is:

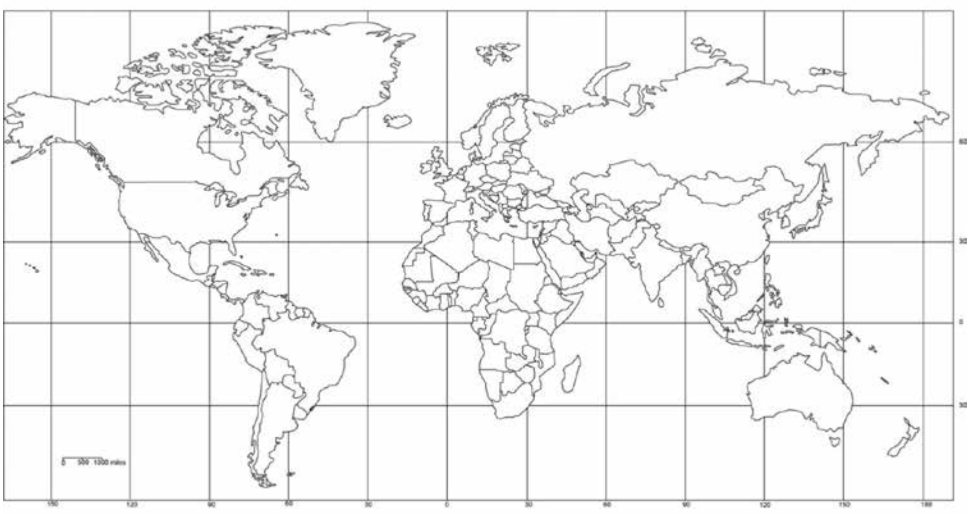
☐ Deep ☐ Surface ☐ I don't know

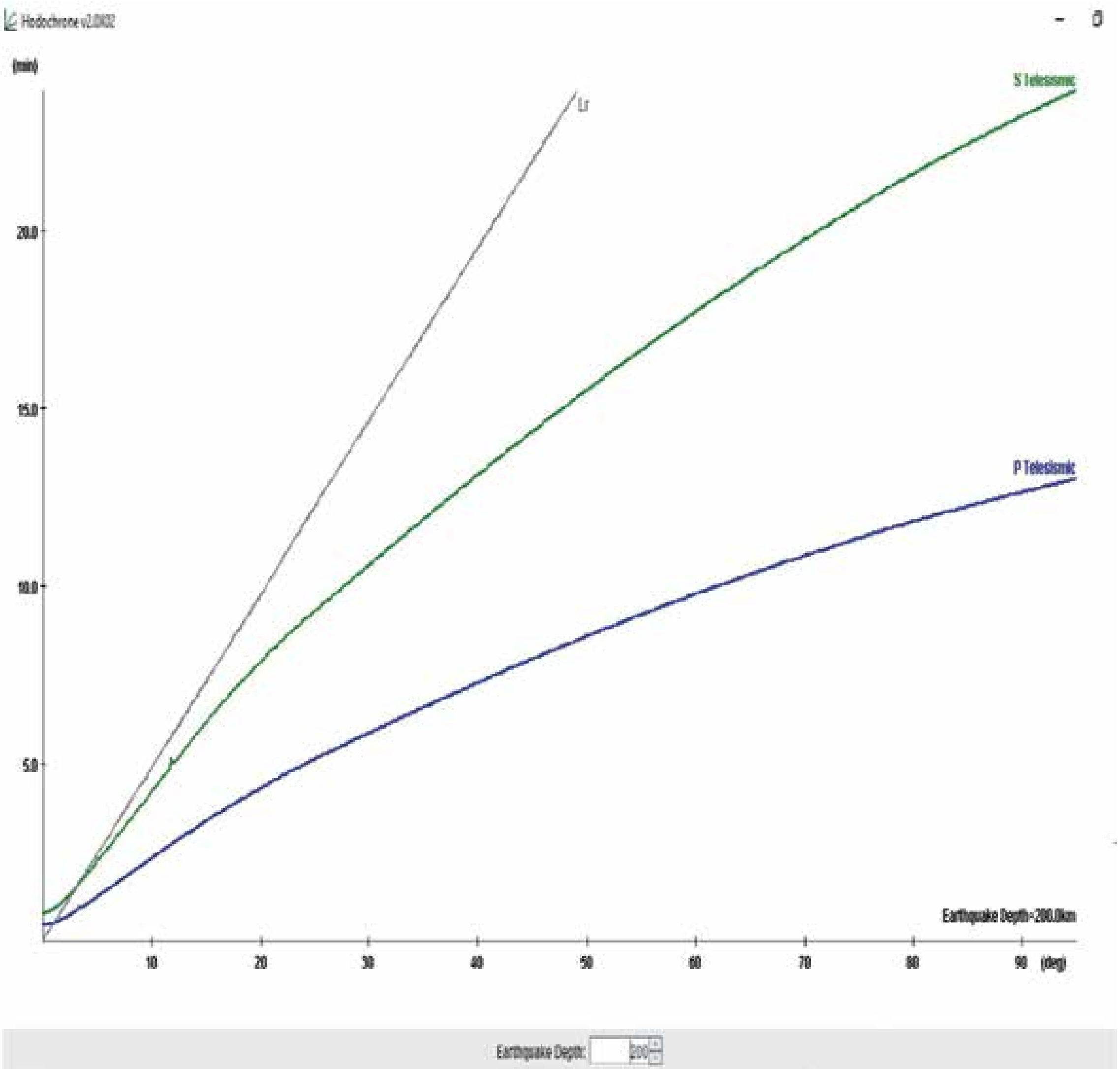
Work table
Consider the information you can find in the directory on the desktop of your pc. Fill the table below reporting the name and the geographical coordinates of your seismic station. Then ask the members of the other research teams and report also the names and the coordinates of their own stations.

Seismic station (Acronym)	Location	Latitude	Longitude	Distance (°)	Distance (km)

Once you will have determined the distance between your station and the epicentre of the earthquake (see next page), put it into the table and then do the same for the stations of the other teams.
Now try to situate on the World map below all the seismic stations in their right places:

World Mercator Projection





Now open the seismograms from the directory and try to individuate the first arrivals of P and S waves. Once you will have done it, using a ruler report the values of their difference (TS – TP) into the hodochrones' graph in the right scale with the y-axes. The distance should find its right place between the two curves describing respectively the trend of the arrival of P and S waves depending on the distance (expressed in degree °). Once you will have gathered the distance in degree multiply it by 111 km to get the distance in km and report it in the table above.

“How to estimate the Magnitude of an earthquake”

This lesson plan was developed according to the Italian national curriculum

Introduction:

On July 2016, a seismic network was installed in the headquarters of the partners’ organizations of the Erasmus + Schools Study Earthquakes (SSE) project. The network is composed by five TC1 type electro-magnetic seismometers provided by the National Observatory of Athens - the leading organization of the project - placed respectively in Athens, Sofia, Nicosia, Izmir and Naples. During the first half of 2017, more seismometers will be installed in some high schools in these countries.

On August 24th, a seismic crisis in central Italy caused victims and damages. The main shocks occurred from August to October were well recorded by all the seismometers of the SSE’s network. Moreover, the seismometer installed in Città della Scienza (the headquarter of Fondazione Idis), being the closest to the epicenters, recorded also the lighter aftershocks occurred after the main ones. All these shocks occurred 200 -250 km away from this seismic station, hence their recordings could be the basic tool to develop this lesson plan for the 12th and 13th school grades, that focuses on the concept of Magnitude and its physical mean.

Introduzione:

Schools Study Earthquakes è progetto europeo che rientra nella misura KA2 (Cooperation for Innovation and the Exchange of Good Practices) del programma Erasmus+, ed è finalizzato all’elaborazione e alla sperimentazione di buone pratiche nell’ambito dell’educazione scientifica a scuola con particolare riferimento alle scienze della Terra e allo studio dei terremoti. SSE ha avuto inizio a settembre 2015 e terminerà ad agosto 2017.

Nell’ambito del progetto, a luglio 2016 è stato realizzato il primo nucleo di una rete sismica tramite l’installazione di sismometri didattici presso le sedi delle organizzazioni partner del progetto stesso situate rispettivamente ad Atene, Smirne, Nicosia, Sofia e Napoli. Nel corso della prima metà del 2017 ulteriori sismometri saranno temporaneamente installati presso diverse scuole coinvolte nelle attività del progetto e aventi sede nei paesi di appartenenza delle organizzazioni partner. Gli allievi delle scuole coinvolte saranno addestrati nell’utilizzo dei suddetti sismometri, e nell’estrapolazione, nell’elaborazione e nell’interpretazione dei da questi acquisiti.

Per la realizzazione della rete sismica sono stati utilizzati dei sismometri TC1 a una componente verticale forniti dall’Osservatorio Nazionale di Atene, organizzazione capofila del progetto. I sismometri TC1 sono concepiti per finalità didattiche e realizzati con materiali di uso comune, ma sono comunque in grado di rivelare le vibrazioni indotte nel suolo dal passaggio di onde generate da terremoti locali di bassa Magnitudo o da terremoti di alta magnitudo generatisi anche a grandissime distanze dalle stazioni stesse.

A partire dal 24 agosto 2016, ha avuto inizio una drammatica crisi sismica che ha colpito l’Italia centrale provocando vittime e danni. La crisi si è protratta fino al successivo ottobre e ha visto il suo culmine con una scossa di Magnitudo 6,5 occorsa il giorno 30 di quello stesso mese.

Le scosse più violente occorse durante la crisi sono state chiaramente registrate da tutti i sismometri della rete SSE mentre il sismografo installato a Città della Scienza, la sede della Fondazione Idis, è riuscito a registrare chiaramente anche diverse repliche di più bassa Magnitudo essendo esso quello più vicino agli epicentri delle scosse. Tutte le scosse che hanno caratterizzato la crisi sismica si sono verificate a una distanza epicentrale compresa fra 200 e 250 km dalla stazione di Città della Scienza.

Questi dati possono rappresentare pertanto la base per lo sviluppo di un'attività didattica rivolta agli studenti degli ultimi anni delle scuole superiori, e focalizzata sul concetto di Magnitudo, sul suo significato fisico e sulla sua determinazione.

Il concetto di Magnitudo fu introdotto nel 1935 da Charles Richter in collaborazione con Beno Gutenberg allo scopo di definire in maniera univoca l'entità di un terremoto facendo riferimento alla quantità di energia liberata durante l'evento, e in analogia con la classificazione delle stelle effettuata dagli astronomi in base alla loro luminosità. La magnitudo del terremoto è ricavata dall'ampiezza massima delle oscillazioni del suolo misurate da uno strumento standard, e dalla distanza tra il punto di misurazione e l'epicentro del sisma. La Magnitudo è espressa come un logaritmo decimale allo scopo di definire in un intervallo numerico piuttosto ristretto sia sismi appena avvertibili sia terremoti giganti: in pratica, a ogni aumento di un'unità nella magnitudo corrisponde un aumento di 10 volte nell'ampiezza misurata sul sismogramma, e un rilascio di energia circa 30 volte maggiore. Sulla scala Richter la magnitudo è espressa in numeri interi e frazioni decimali. I terremoti di magnitudo inferiore a 2,0 sono definiti "eventi strumentali", cioè non sono generalmente percepiti dalle persone e sono rivelati solo dai sismografi più vicino al loro epicentro. I terremoti di magnitudo superiore a 4,5 sono invece abbastanza forti per essere registrati anche a grandissime distanze, per lo meno dai sismografi più sensibili. Infine i terremoti con magnitudo superiore a 8,0 sono definiti "terremoti giganti".

La magnitudo così come definita da Richter è indicata come M_L (magnitudo locale) ed è espressa dal logaritmo decimale dell'ampiezza massima della traccia con la quale un sismografo di tipo Wood-Anderson1 calibrato in maniera "standard"[2] registrerebbe un terremoto se fosse installato a 100 km di distanza dall'epicentro. La formula per il calcolo della M_L sarebbe quindi:

$$M_L = \log A$$

dove M_L è appunto la magnitudo Richter, o magnitudo locale, e A è la misura del picco massimo di ampiezza del sismogramma espressa in micrometri (?).

Poiché in caso di terremoto è altamente improbabile che un sismografo si trovi esattamente a 100 km dall'epicentro, la M_L dell'evento può essere determinata correggendo la formula precedente qualora si conosca la legge di attenuazione dell'ampiezza delle onde sismiche al variare della distanza epicentrale.

Richter ricavò questa legge empiricamente basandosi sulle registrazioni di numerosi terremoti superficiali avvenuti nella California meridionale con distanze epicentrali comprese tra 20 e 600 km. Raccolse una grossa serie di dati riassumibili in due equazioni:

$M_L = \log A + 1{,}6 \log D - 0{,}15$ per gli eventi distanti meno di 200 km
$M_L = \log A + 3{,}0 \log D - 3{,}38$ per quelli compresi tra 200 e 600 km.

Le costanti numeriche delle due formule sono sostanzialmente valide per quella regione degli Stati Uniti, mentre A è l'ampiezza massima del sismogramma espressa in micrometri e D è la distanza epicentrale espressa in chilometri.
In ogni caso la misura della magnitudo (M) è data da una formula generale del seguente tipo:

$$M = \log (A/T) + f(D, h) + C_S + C_r$$

dove A è il massimo spostamento del suolo prodotto dalla fase sismica sulla quale la sca-

1. Il Wood-Anderson è un sismografo a torsione a tre componenti in uso fino agli anni '60 del novecento.

2. Gli standard di calibrazione per un sismografo Wood-Anderson sono fattore di amplificazione pari a 2.800, periodo proprio di risonanza corrispondente a 0,8 secondi, e costante di smorzamento 0,8.

la di magnitudo è basata, T è il periodo del segnale misurato dal sismografo (in pratica la distanza temporale tra due picchi consecutivi di quella fase), f è un fattore di correzione funzione della distanza epicentrale (D) e della profondità ipocentrale (h), CS è un fattore di correzione derivante dalla caratteristiche geologiche del sito della stazione sismica, mentre Cr è un fattore di correzione analogo per il sito della sorgente sismica.

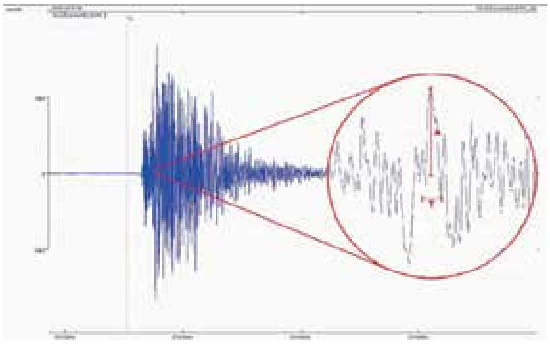


Fig. 1

Per estendere l'idea originale di Richter alla misura di terremoti sulle medie e grandi distanze e a registrazioni effettuate con altri tipi di sismometro caratterizzati da altre frequenze di risonanza propria, furono in seguito introdotte delle nuove scale di magnitudo ma definite sempre in modo che, per lo meno nel proprio range di validità, fossero comunque equivalenti alla magnitudo Richter: la magnitudo delle onde di volume mb, e la magnitudo delle onde di superficie, Ms.

Si utilizzano inoltre altre due scale di magnitudo. Una è la cosiddetta magnitudo del momento sismico, o Mw, introdotta per misurare i terremoti più forti poiché l'ampiezza massima delle registrazioni, superato il valore 6,5 della M_L, tende ad attestarsi su un valore limite. Inoltre la Mw tiene conto, oltre che del movimento del suolo, anche dell'energia rilasciata nell'evento. L'altra scala, Md, misura invece la durata di un terremoto, anziché la solita ampiezza massima, e si applica solo agli eventi locali.

Il calcolo della magnitudo in pratica

La determinare della magnitudo di un terremoto è un'operazione particolarmente complicata, e l'impresa diventa ancora più ardua quando viene tentata ricorrendo esclusivamente ai dati ricavati da un proprio sismografo per usi didattici e non si dispone delle strumentazioni e delle conoscenze proprie di un'organizzazione di ricerca. In particolare sono tre i principali problemi che condizionano la determinazione della magnitudo di un terremoto:

- Errore sistematico e casuale - ogni stazione sismica misura la magnitudo con un errore sistematico finanche di 0,3 gradi in più o in meno. L'entità di questo errore può essere valutata confrontando i valori di magnitudo determinati con le registrazioni effettuate dal proprio strumento per diversi terremoti con quelli riportati per gli stessi eventi sui database dei centri di ricerca disponibili in internet. La media degli scarti così determinati per ciascuno di questi raffronti ci permette di stimare l'entità dell'errore sistematico ma non può certo costituire un fattore di correzione per la determinazione della magnitudo. Inoltre, utilizzando uno strumento a un'unica componente orizzontale, l'ampiezza del tracciato dipende dall'orientazione dello strumento rispetto alla direzione di provenienza delle onde sismiche.
- Caratteristiche geologiche locali ed effetti di sito – i fattori di correzione riportati come CS e Cr in una formula esposta in precedenza dipendono dalle caratteristiche geologiche sia dell'area della sorgente sismica sia del sito dove è collocato il sismometro. Per esempio i valori di correzione utilizzati dallo stesso Richter sono validi sostanzialmente per la California meridionale ma non funzionano per altre aree della Terra.
- Dipendenza dallo strumento - l'equazione per il calcolo della magnitudo locale secondo la formulazione di Richter esposta in precedenza si basa su misure ottenute con sismografi orizzontali tipo Wood-Anderson calibrati secondo standard predeterminati. Utilizzando uno strumento con diversa amplificazione

e diversa frequenza di risonanza propria, le magnitudo così determinate per diversi eventi rappresenterebbero valori di una scala a sé stante non commensurabile con quella di riferimento univocamente accettata.

I tre problemi sopra esposti possono essere aggirati utilizzando un certo numero di registrazioni sismiche effettuate con il proprio sismografo3 per, sulla base di questi dati, determinando empiricamente un'equazione per la stima della magnitudo appropriata per il proprio strumento e per il sito nel quale questo è installato.

Inoltre è necessario "tarare" le proprie registrazioni ricorrendo ai valori di magnitudo relativi agli stessi eventi sismici forniti via internet dai database degli istituto di ricerca nel settore.

Come già detto in precedenza, la formula generica che esprime la magnitudo di un terremoto locale è M_L = log A + f(D) + costante, dove A è l'ampiezza massima del sismogramma e f(D) è una funzione della distanza epicentrale e, considerando anche gli effetti dovuti alle caratteristiche del proprio sismografo e gli effetti di sito una formula generale completa è:

$$M_L = \log A + a\log D - b$$

Pertanto è necessario determinare gli esponenti a e b di una formula generale di questo tipo. Quindi, disponendo di almeno due registrazioni sismiche e delle informazioni sulle magnitudo locali e sulle coordinate epicentrali dei due terremoti a esse correlati, che chiameremo genericamente evento 1 ed evento 2, il valore degli esponenti a e b può essere determinato risolvendo un sistema di due equazioni lineari a due incognite:

$$M_L1 = \log A_1 + a\cdot\log D_1 - b$$
$$M_L2 = \log A_2 + a\cdot\log D_2 - b$$

Per esempio, si considerino due terremoti di differente magnitudo, verificatisi a diversa distanza dalla stazione sismica e che abbiano prodotto ampiezze massime di registrazione differenti:

evento	Magnitudo locale (M_L)	Distanza epicentrale (D)	Ampiezza massima (A)
1	6,5	270 km	10 mm
2	3,6	60 km	0,25 mm

Facendo riferimento alla formula generale e risolvendo il sistema di due equazioni si avrà:

a = 0,33
b = -3,61
e quindi

$$M_L = \log A + 0{,}33\log D + 3{,}61$$

Pertanto, qualora si verificasse un terremoto a 120 km di distanza epicentrale dalla stessa stazione che producesse una ampiezza massima di spostamento sul sismogramma di 2,4 mm, sostituendo questi valori nell'equazione di riferimento si potrebbe facilmente calcolare la sua magnitudo locale.

$$M_L = 4{,}68$$

Calcolo della magnitudo mediante la durata della registrazione

Per quanto abbastanza elementare dal punto di vista concettuale, il metodo prima esposto risulta molto poco affidabile in quanto piccolissime variazioni A e D nelle formule possono portare a variazioni piuttosto significative del valore di magnitudo locale calcolato.

Disponendo di un'unica stazione sismica si può stimare con migliore accuratezza la magnitudo di un terremoto basandosi sulla durata della registrazione. È non infatti che, a parità di distanza epicentrale, la durata della registrazione sismica aumenta la magnitudo del terremoto.

A questo proposito si può usare quindi un'ap-

3. A questo scopo si può utilizzare un sensore verticale o almeno due sensori orizzontali orientati perpendicolarmente fra loro.

posita funzione del programma Winquake e, per illustrare la procedura si parte direttamente da un esempio pratico. La figura 2 mostra le registrazione della scossa principale del terremoto di Amatrice del 24 agosto 2016 registrata dalla stazione sismica di Città della Scienza.

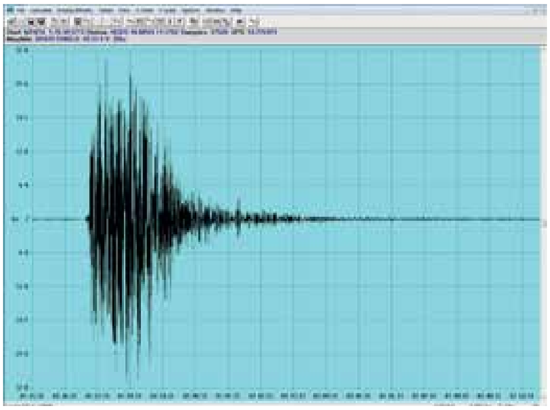


Fig. 2

Si è già detto che, a parità di distanza epicentrale, la durata della registrazione di un evento sismico aumenta all'aumentare della magnitudo dello stesso.

Per poter stimare quindi la magnitudo dell'evento in oggetto è necessario in primo luogo determinarne la distanza epicentrale. È necessario quindi dilatare la registrazione tramite la funzione X-scale per poter meglio visualizzare i primi arrivi delle onde P ed S, per poi marcarli con i traguardi che possono essere attivati tramite la funzione P S. In alto nella schermata, come evidenziato in figura 3 apparirà il valore della distanza epicentrale che, nel nostro caso, corrisponde a circa 225 km.

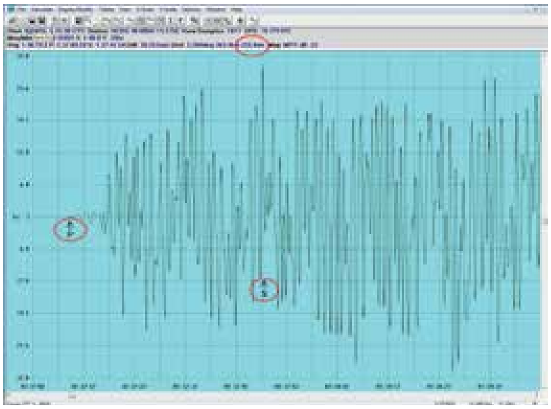
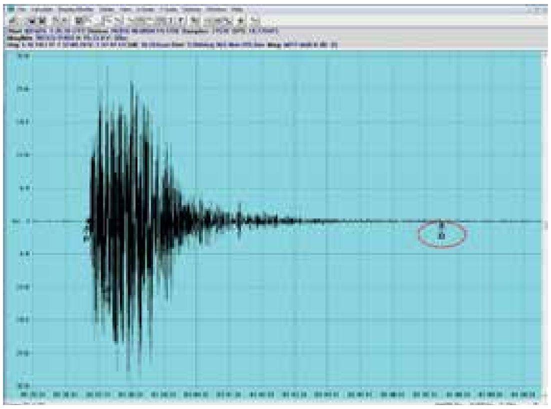


Fig. 3

A questo punto, sempre tramite la funzione X-scale, si può nuovamente comprimere la registrazione e, attivando la funzione Md, sulla traccia apparirà il traguardo D per marcare la fine della registrazione. Il traguardo D va collocato laddove l'ampiezza delle oscillazioni provocate dal sisma vanno a confondersi con quelle dovute al rumore di fondo del sito. In alto della schermata apparirà anche il valore Md che in questo caso corrisponde a 6,0 come determinato anche dai ricercatori dell'INGV (Fig. 4).



"Study of Earthquakes"

School-project plan, resources and classroom activities for high-school students (ages 15-18) in accordance with the Greek Science Curriculum

General description:

(Applies also as lesson plan for junior high-school "Earthquakes and tectonic plates")

Orientation phase

In this phase the objective is to provoke students' interest and curiosity about the earthquake phenomenon. If a significant earthquake occurred recently at local, national or international level, the teacher can ask students to recall and mention their experiences (of what they felt, what they or others did and reacted, what is/was the understanding of what happened etc.). A related video or news broadcast about an earthquake event may be shown as well. After that some main general questions can follow, for example: "What is an earthquake?", "How and why earthquakes happen?", "Are they frequent in Greece?", "Are they frequent in other countries? Which countries?", "How can we study earthquakes?", "What parameters can we study?", ''What kind of equipment and tools do scientist use to measure earthquakes?''. Students may be requested to form teams to discuss their ideas about earthquakes and present some of them to the rest of students.

Conceptualization phase

In this phase, more specific questions, hypotheses and information can be formulated and gathered about earthquakes and tectonic plates, earthquake parameters, focus, epicenter, magnitude, intensity, faults, generation mechanism, seismic waves and seismographs. Students ask questions and make hypotheses based on their observations or preliminary knowledge and understanding which will then investigate.

Investigation phase

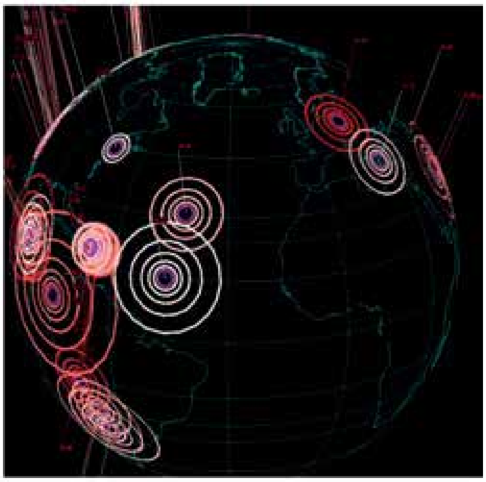
Students work in teams to do their studies and work like seismologists. They use online resources of earthquake data and seismograms or they may be given worksheets or printed seismographic data in paper. Students follow the investigation plan which can be adjusted according to their needs, their inquiry skills and knowledge. Through this phase students learn to identify and describe types of seismic waves from seismograms of real earthquakes, they gather and interpret data like real scientist do and finally measure and determine the epicenter and magnitude of real earthquakes and compare their results and findings.

During the investigation phase, teachers' main role is to guide and assist their students in their tasks. Depending on students' skills and competences the guidance may be more focused to avoid students misdirect their focus of work or misinterpret their findings.

Conclusion phase

During this phase students compare their results, conclude on what they found and discuss the overall procedure they followed. Within the context of a school –project they may get together all the pieces of their work, what they have learnt and how and present it to the whole classroom or to the school community. As a closing activity students discuss and present through videos or poster guides precaution and safety measures that they should follow in the event of an earthquake.

Introduction and orientation
(Provoke curiosity)
Observe carefully the following images:



Have you ever wondered what an earthquake is?
Have you ever experienced an earthquake?
Watch the following video of earthquakes happening all over the world:

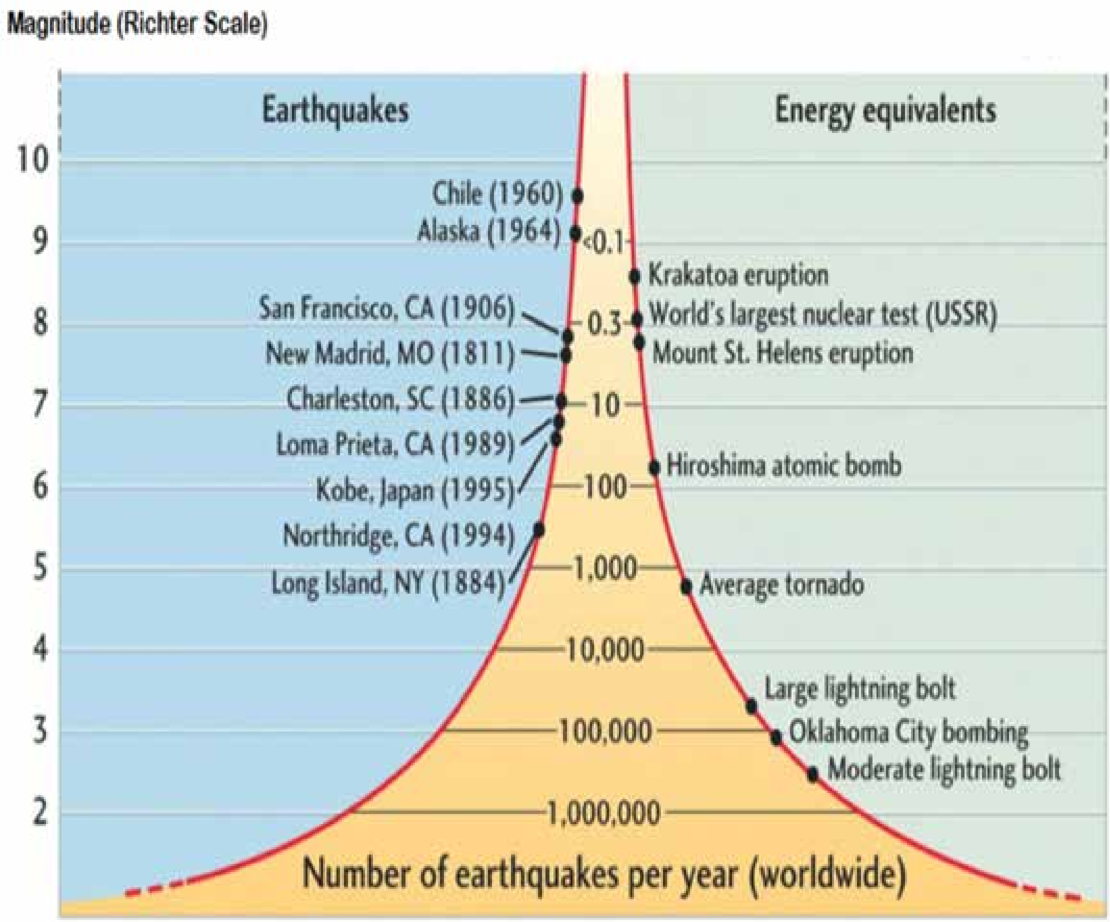
http://video.nationalgeographic.com/video/earthquake-montage
Watch the following video on the Earthquake of San-Francisco in 1989:
http://www.history.com/topics/san-francisco/videos/mega-disasters-san-francisco-earthquake
Discuss your ideas concerning earthquakes.
How do you believe they are generated?

Define goals and/or questions from current knowledge

Definition:
An Earthquake is the shaking and vibration at the surface of the earth resulting from underground movement along a fault plane or from volcanic activity.

Earthquake Scales:
As we have seen, earthquakes can cause major destructions. In order to describe the severity of these destructions, scientists have invented the Richter and Mercalli scales.

The **Richter magnitude scale** is a measure of the energy released by an earthquake. The earthquake magnitude M ranges from 1 to 10, with 1 being equal to the vibration of the earth when a train passes by. When earthquake A has one unit more magnitude than earthquake B, this means that A is 10 times stronger than B, or A releases 31.6 times more energy than B!! The Richter scale is a logarithmic scale.
Below you can see the Richter scale and the comparison of the energy release:

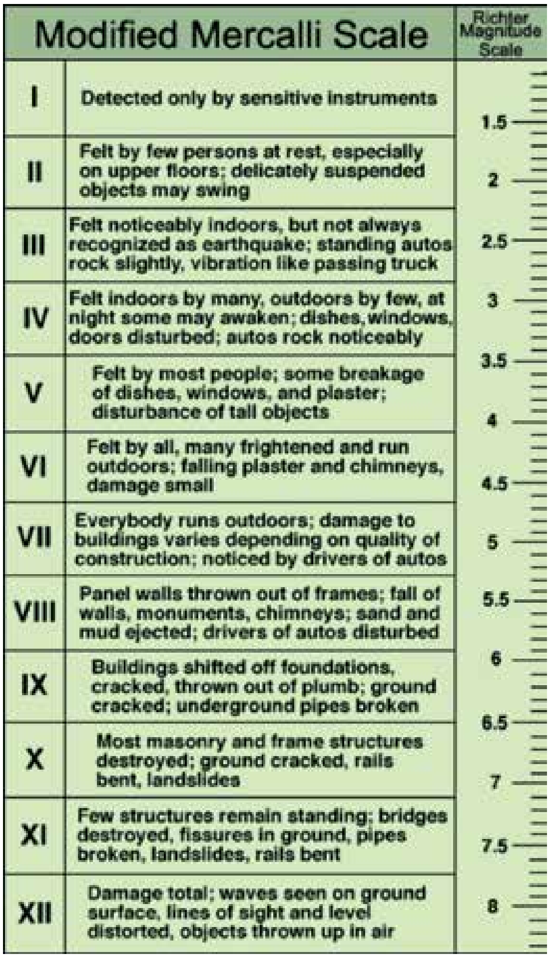


Discuss your findings: how does an earthquake of magnitude 8 compare with the Hiroshima atomic bomb?

The **Mercalli intensity scale** is a measure of the observed effects of an earthquake to both natural and human environment.

The value of the Mercalli scale depends on the distance from the epicentre of the earthquake (aka its source) and on the structure of the ground.

Look at the picture below and discuss the relations between the Mercalli and the Richter scales. In the picture, the term: Scale refers to Mercalli and Magnitude to the Richter scale.



Modified Mercalli Scale	
I	Detected only by sensitive instruments
II	Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing
III	Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibration like passing truck
IV	Felt indoors by many, outdoors by few, at night some may awaken; dishes, windows, doors disturbed; autos rock noticeably
V	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects
VI	Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small
VII	Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos
VIII	Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed
IX	Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken
X	Most masonry and frame structures destroyed; ground cracked, rails bent, landslides
XI	Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent
XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up in air

Activity!

If you have experienced an earthquake try to find out what affects you observe on the Mercalli scale. Then go to the previous picture and make an estimate of the Earthquake's magnitude in the Richter scale.

Compare your finding with the original reports from the news on the magnitude of the earthquake.Was this method successful?

Define goals and/or questions from current knowledge

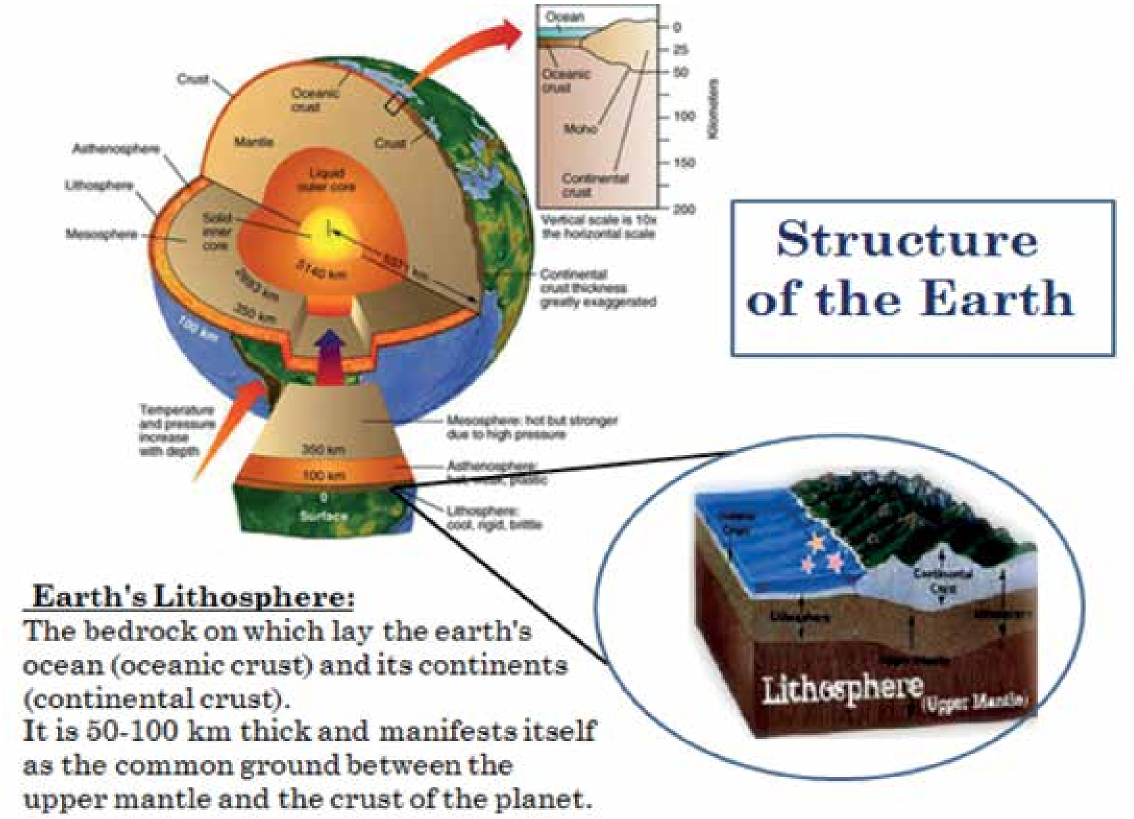
Why do earthquakes occur?

Suppose that you live in the middle of Siberia while a friend of yours lives in Turkey. Which of the two is more likely to experience an earthquake?

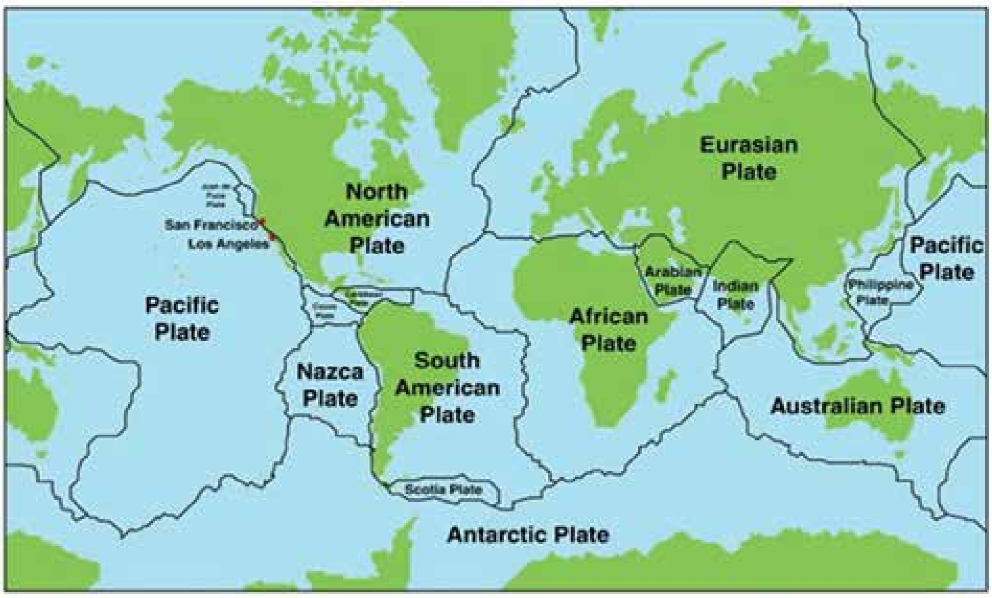
Back in the 60's, people knew that earthquakes and volcanoes tended to appear in certain parts of the world. They knew for example the so called "ring of fire": a belt of going around the edge of the Pacific Ocean in which exist active volcanoes and there is strong seismic activity. The belt goes through New Zealand, Indonesia, Japan, Alaska and the North America. On the contrary, places like Britain have neither active volcanoes nor strong seismic activity.

People assumed that the Earth's crust was ripped open along these "lines of weakness" for some reason allowing the molten rock from under the surface to pour out in volcanoes. The reasons for these cracks of the Earth were unknown. Maybe it was just chance. With this course of thought, a crack might appear anywhere in the world at any time creating volcanoes and producing seismic activity!

Below you can see an image of the structure of the earth. Special attention needs to be paid on the Lithosphere:

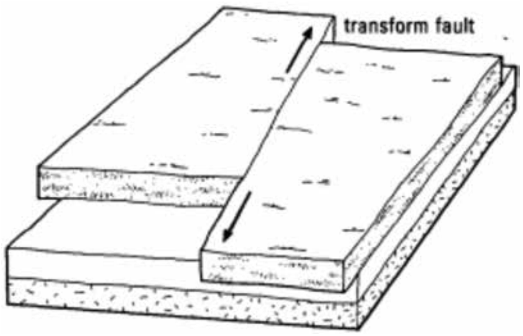


According to the theory of tectonic plates, first developed by Wegener, the earth's lithosphere is not uniform. On the contrary it consists of the lithospheric plates which slide on top of the upper mantle.

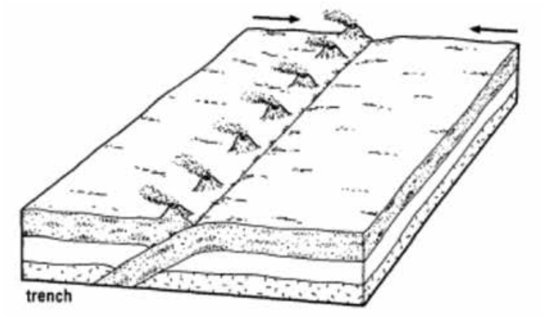


The plates are constantly moving with respect to each other and colliding.

In cases such as the San Andreas Fault in California, the tectonic theory supports that the plates push past each other as we can see below:

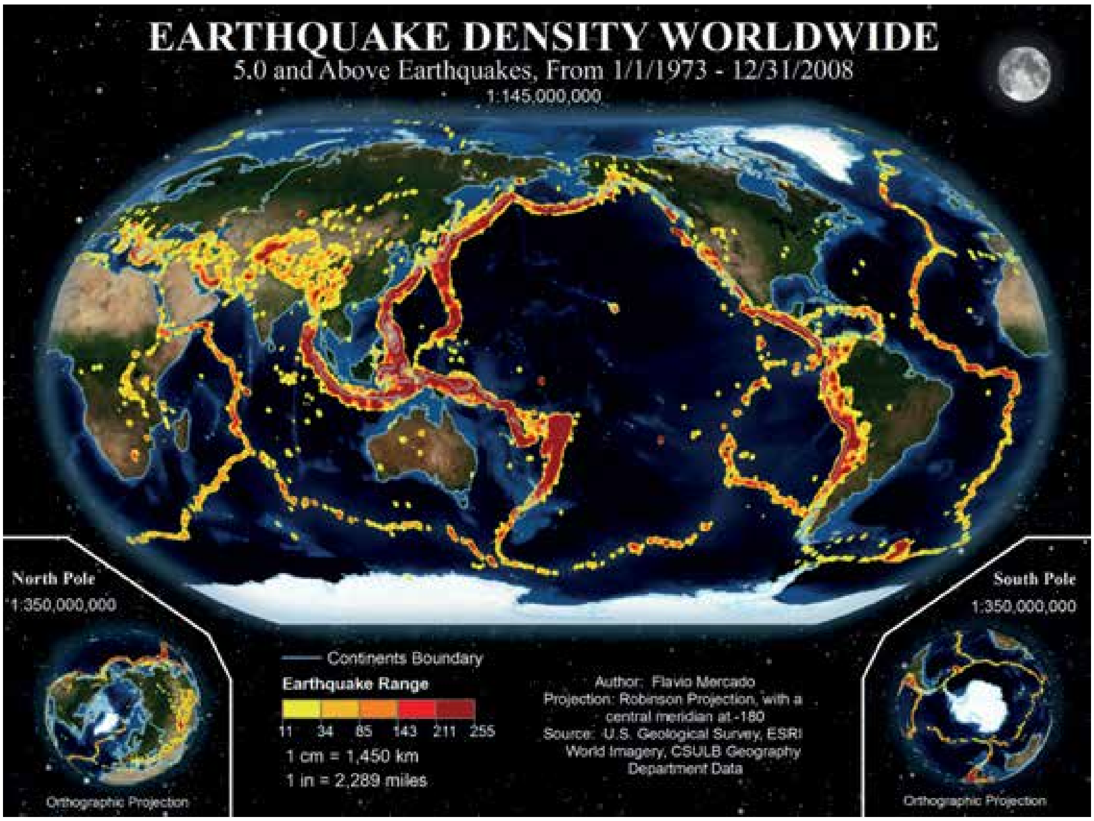


There are also cases such as the one illustrated below, that a plate is pushed below the surrounding plates and melts when it goes deep inside. This leads to extreme volcanic and earthquake activity and the creation of mountains as happens in Japan for example.



Earthquake Generation Mechanism:
Very high tensions are developed around the borders between plates.
Energy is released in the form of seismic waves which travel very long distances and can be detected on the earth.

Observe the following map and discuss:



Is there any correlation between the tectonic plates boundaries and the seismic activity distribution on the earth?

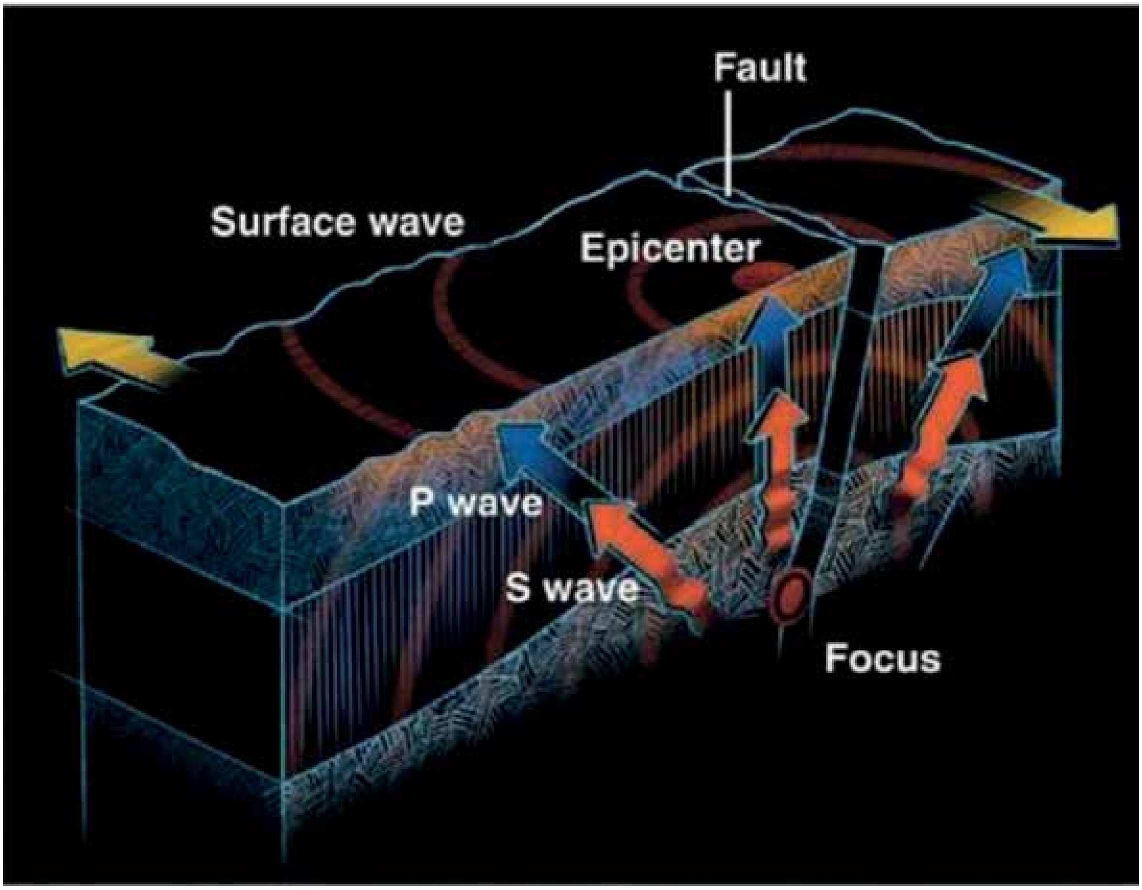
Fundamental Characteristics of Earthquakes

Observe the picture below: You can observe the seismic waves expanding from a source inside the earth. This "source" of the seismic waves is the Focus (or hypocenter).

Now, let's draw a vertical line that starts from the focus and ends at the surface of the earth. The point on the surface of the earth exactly above the focus is called the "epicenter". The length of the line is called the "depth" of the earthquake. Shallow earthquakes are between 0 and 70 km deep; intermediate earthquakes, 70 - 300 km deep; and deep earthquakes, 300 - 700 km deep. In general, the term "deep-focus earthquakes" is applied to earthquakes deeper than 70 km. All earthquakes deeper than 70 km are localized within great slabs of shallow lithosphere that are sinking into the Earth's mantle.

A fault is a fracture along which the blocks of crust on either side have moved relative to one another parallel to the fracture.

Now that we have a good idea on why earthquakes occur and what their main characteristics are, we are ready to become young seismologists and learn the techniques that help us find the epicenter and the magnitude of an earthquake!!



Generation of Hypotheses or preliminary explanations

Now that we have comprehended the main characteristics of earthquakes, let's discuss the fundamentals of earthquake detection:

During an earthquake, a fraction of the collision energy on its focus is radiated in the form of seismic waves.

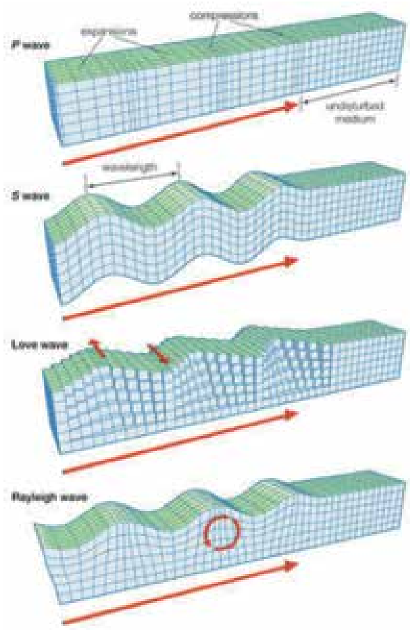
Seismic Waves

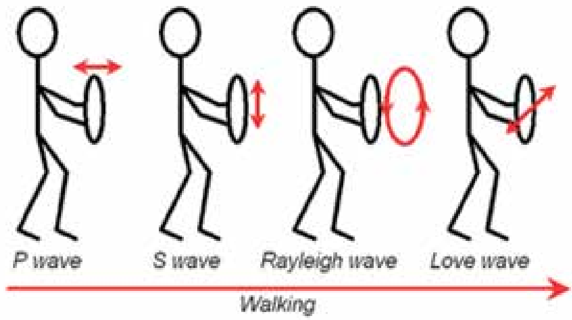
There are several different kinds of seismic waves, and they all move in different ways. The two main types of waves are **body waves** and **surface waves**. Earthquakes radiate seismic energy as both body and surface waves.

Body waves have high frequency and can travel through the earth's inner layers. They are divided in two categories: The P- Waves (P: Primary), which arrive first, and the S- Waves (S: Secondary) which arrive after the P- Waves. This time difference between P- and S- waves is one of the most prominent characteristics which is taken into account when we detect earthquakes.

Surface Waves have lower frequency than the body waves and arrive after them during the earthquake. They can only move along the surface of the planet like ripples on water. Surface waves divide in Love waves and Rayleigh waves and are responsible for the majority of destruction taking place during an earthquake.

Look at the pictures below:





Can you describe the different kinds of motion that earth is being put into due to the different kinds of seismic waves? Can you replicate the waves using your body?

Detecting Earthquakes
What do you think: can we determine the epicentre and the magnitude of an earthquake ourselves?

Discuss: What methods would you propose in order to locate the epicentre and the strength of an earthquake?

In order to detect earthquakes scientists use seismographs or seismometers.

From them, one gets the seismogram:
Below you can see a seismogram and the relevant details that can be extracted from it.

Take some time to comprehend the characteristics of a seismogram. In the horizontal axis we measure time (minutes or seconds) and in the vertical axis we measure amplitude (mm).

Using a seismogram, we can extract two kinds of information:

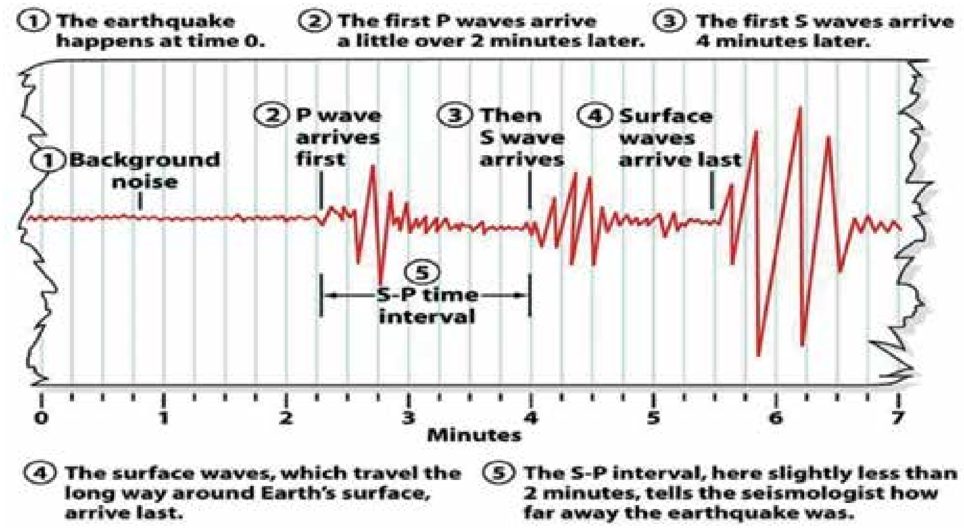
Timing and amplitude
The timing refers mainly to the time difference between the two components of body waves, the S- and P- waves which can be employed to find the location of the epicentre of the earthquake.

The amplitude refers to the oscillation amplitude of the ground during an earthquake. This amplitude is directly related to the energy radiated in the form of waves during an earthquake and can be measured to determine the magnitude of the earthquake in the Richter scale.

In the following activity, we will employ the method of trilateration in order to find the epicentre of an earthquake using real data, and then measure the earthquake's magnitude using a Richter nomogram.

Let's solve a simple exercise using simple physics and maths:

Suppose that we have two waves A,B traveling in a straight line and originating from the same point x=0 simultaneously.



Wave A travels with uA = 2m/s and wave B travels with uB = 1m/s.

Three observers: Nick, Mary and Jessy are standing at distances 2m, 10m and 100m from the wave source.

a) Calculate the arrival time of wave A (tA) and of wave B (tB) for each of the observers.
b) Subtract tA from tB for each of the observers.
c) Plot tB-tA with respect to the distance of each observer from the source at your notebook. Does the time difference scale with distance?
d) Using the above plot, predict what will be the time difference at a distance of 300m.

Discuss: Do you think that the method described above has anything to do with the determination of the epicentre of the earthquake?

Plan investigation

PART A - The Earthquake's Epicentre

The problem of finding an earthquake's epicentre is similar to the problem of finding our unknown position using a GPS. In order to achieve it we employ the trilateration technique. Trilateration is defined as the method employed in order to find your unknown location when you know its distance from at least three reference points.

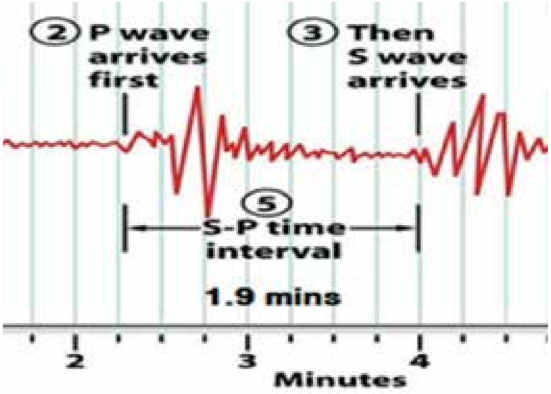
Let's assume that an earthquake happens at an unknown location. The earthquake is detected by at least **three seismic stations** which are flagged in the following map.

* *(The flags are randomly placed for the sake of demonstration)*

Each station is equipped with seismometers which will produce seismograms

The P- wave is the first to arrive and after it the S- wave arrives. After the S- wave the surface waves of the earthquake arrive too.

Using the seismogram, we measure the time interval between the S- and the P- wave as we can see in the picture below. This information will be used in order to find the distance between the epicentre and our station.



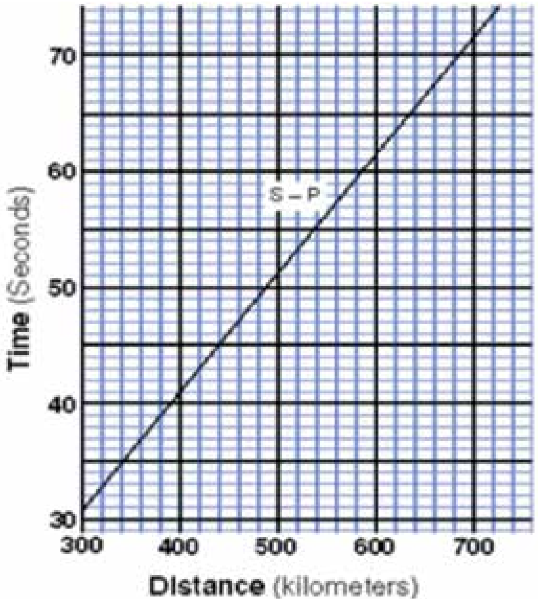
Graph.1: *S-P time interval calculation*

However, seismograms tend to be rather complex. Usually you see wiggles of higher and lower amplitude.

So which wiggles represent the earthquake? The P wave will be the first wiggle that is bigger than the rest of the little ones (the microseisms). Because P waves are the fastest seismic waves, they will usually be the first ones that your seismograph records.

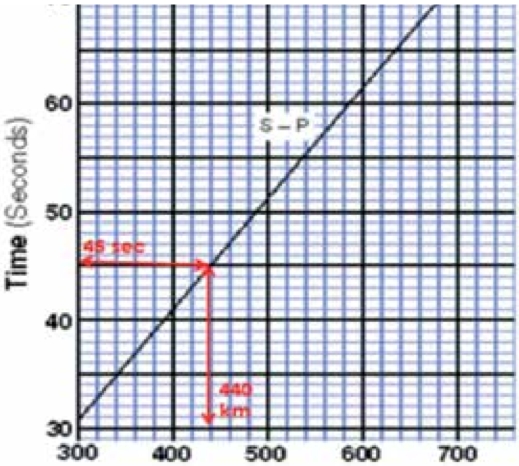
The next set of seismic waves on your seismogram will be the S waves. These are usually bigger than the P waves. The surface waves come later than the S- waves and have lower frequency which means that they are more spread out.

After we measure the time interval between a P- and an S- wave, we need to use these data in order to find the distance of our detector from the epicentre. This is done using the following graph which represents the time vs epicentre distance for S- and P- waves:



Graph.2: *Time vs epicentral distance*

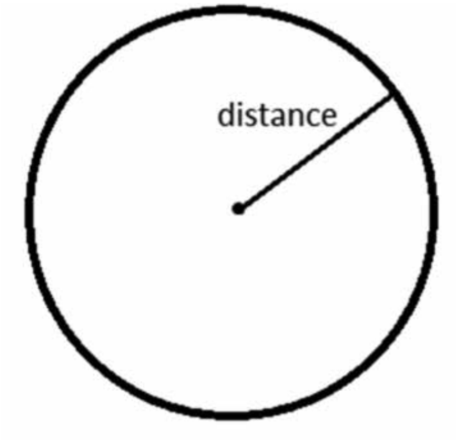
For each station we note the time difference between the S- and the P- waves on the graph. Then we locate the relevant epicentral distance as demonstrated below:



Graph.3: *A time difference of 45 sec is shown to correspond to 440 km epicentral distance*

This procedure is repeated for every station that measures the earthquake.

Why don't we just use data from one station? Because we know the epicenter's distance but we don't know its direction! The epicenter can be anywhere in a radius equal to the epicenter distance.



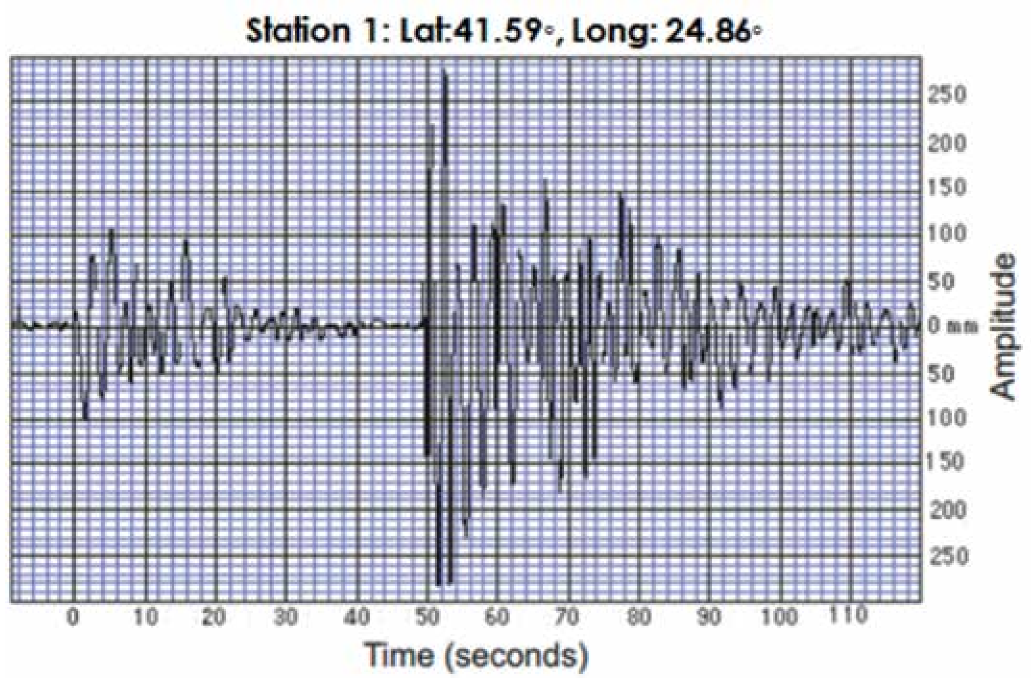
We need at least two more detectors in order to locate the epicentre!
This is done the following way:

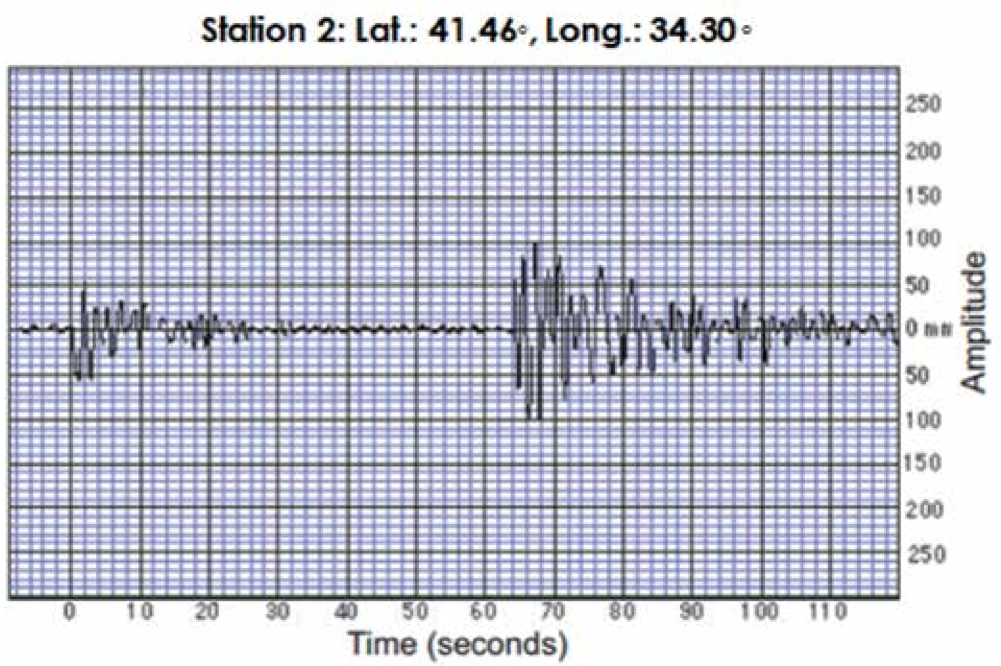
After we obtain the epicenter distance for each station, we draw a circle with its center being on the station and its radius being equal to the epicentre distance. We find the place where the three circles intersect: This is the earthquake's epicentre!

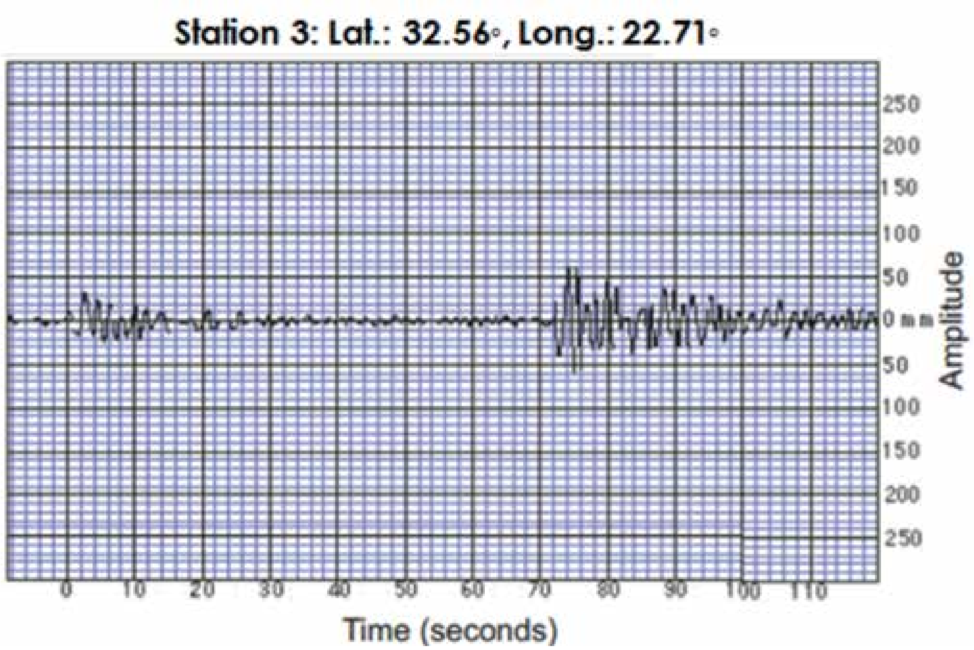
Graph.4: *The trilateration technique*

IMPLEMENTATION

Divide in groups and observe the following three seismograms:
Note the units in the horizontal and the vertical axes.







For each seismogram:

– Determine the arrival time of the S- waves (Ts) and the arrival time of the P- waves (Tp). Subtract them to find the time difference:

ΔT = Ts - Tp

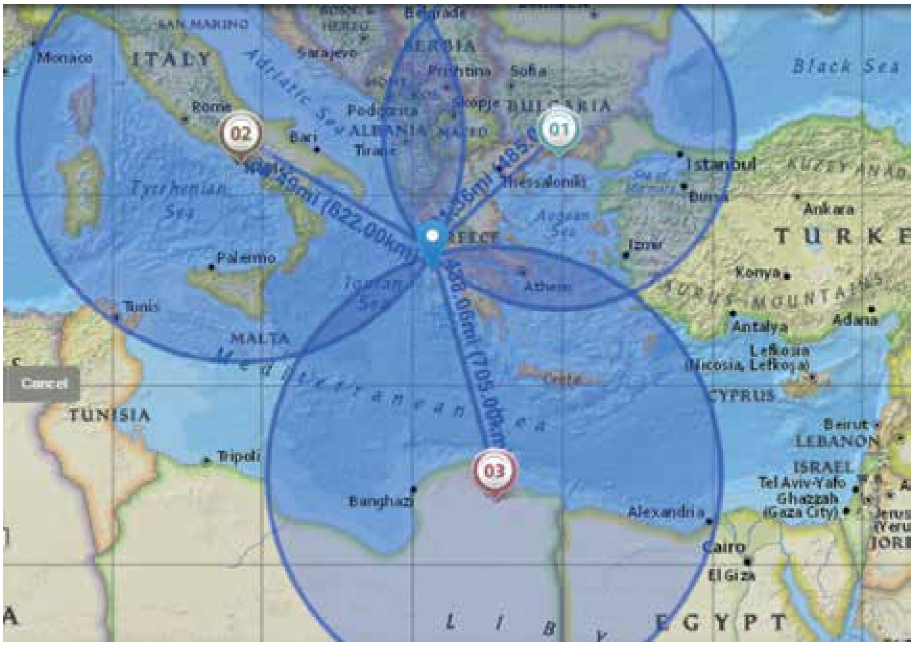
– Write the Ts, Tp, ΔT for each seismogram at a spreadsheet.
– Using graph 2 and the method presented on graph 3, find the epicentral distance (Δ) for each station. Note Δ at the spreadsheet too for each station.
– Now that you have found the epicentral distances for each seismogram, you can apply the trilateration technique to find the epicenter.

The technique will be applied using the Interactive Mapmaker at http://mapmaker.education.nationalgeographic.com/

– Use the guidelines (http://tools.inspiringscience.eu/author/resource/uuid/4624f4e6) on how to calculate the epicenter using the interactive mapmaker.
– Note the coordinates of your epicenter at your notebook.

The epicenter location is at: Lat: 38,67◦, Long: 20,60◦

A correct implementation of the activity will result in the students' obtaining an image like the following for the epicenter location determination:



The correct inputs for the spreadsheet are the following:

Station	Latitude (º)	Longitude (º)	Ts (sec)	Tp (sec)	**ΔT (sec)**	**Δ (km)**	A(mm)
A	41,59	24,86	50	0	50	485	285
B	41,46	34,3	64	0	64	622	100
C	32,56	22,71	72	0	72	705	60

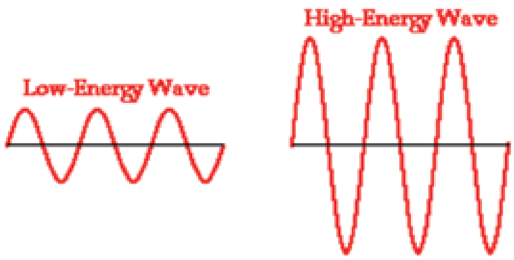
The last column of this table will be filled by the students in the following part of the activity. The next part of the activity: “The Earthquake’s Magnitude” is optional. However, it is suggested that it is implemented for the sake of completeness.

PART B - The Earthquake’s Magnitude

After having completed the determination of the location of an earthquake’s epicenter, the next step is to determine the strength of the earthquake.

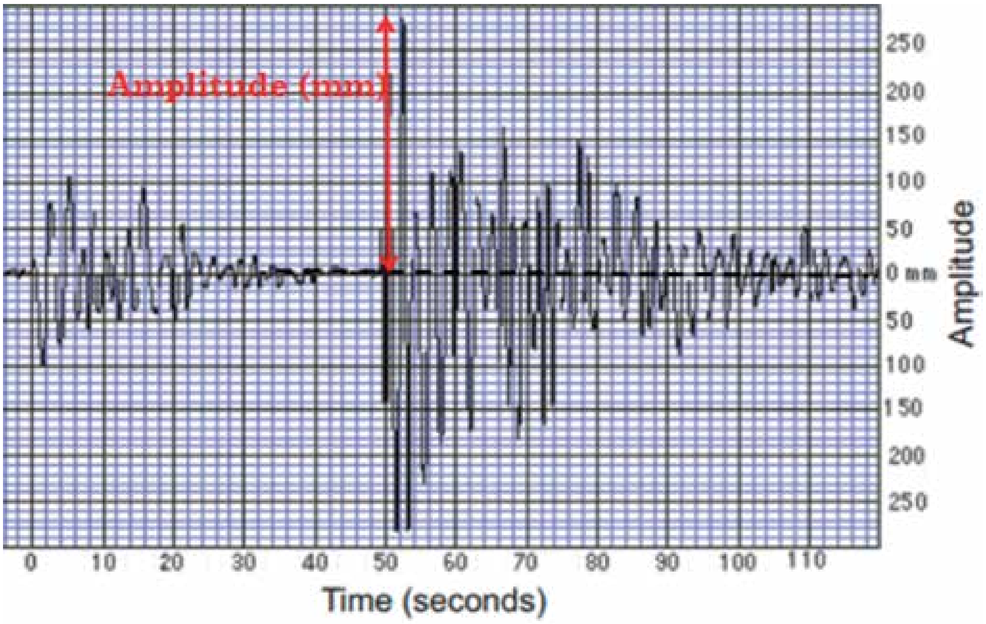
This is done by mesuring the magnitude of the earthquake using the Richter magnitude scale which has been defined previously (Orienting and Asking questions phase). The magnitude of an earthquake is an indicator of the total energy released in form of seismic waves from the rupture in the earth.

The energy and thus the magnitude depend on the amplitude of the seismic waves: As the energy of the seismic waves increases, the amplitude of the ground’s oscillation increases too.



This amplitude can be measured using a seismogram the following way:

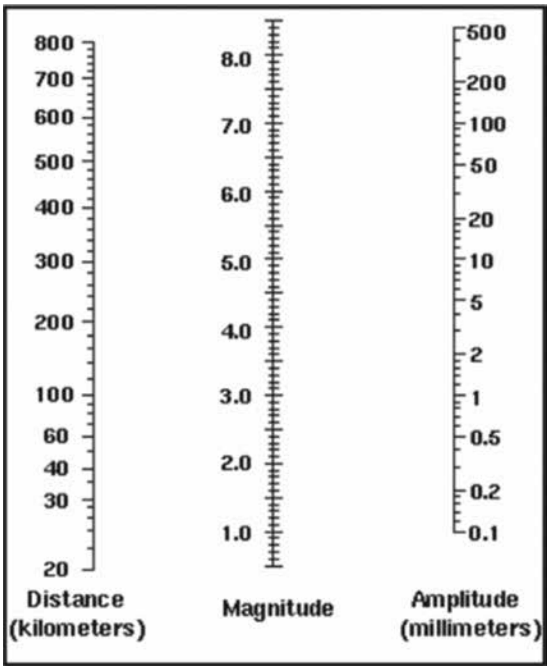
We find the line of zero amplitude and measure the height of the highest S-wave. The amplitude is measured in mm.



Another variable on which the energy and magnitude depend is the epicentric distance of the waves.

If we assume that we observe two earthquakes of the same amplitude, the one originating 100 km further than the other, then we can conclude that the further one carries more energy. This happens because the energy lost by the earthquake during its travel towards the station increases with distance. Therefore, if the amplitude is the same, the initial energy released by the rupture will be greater for the furthest earthquake.

In order to estimate the magnitude of the earthquake, we use the Richter Nomogram:



An earthquake detected by three or more stations will provide us data about:

a) The epicentric distance for each station (Previous activity)
b) The amplitude measured in each station.

Different combinations of distance and amplitude result in different earthquake magnitudes.

In this part of your investigation, you will use the three seismograms presented to you at the previous part of your investigation, in order to determine the magnitude of the earthquake.

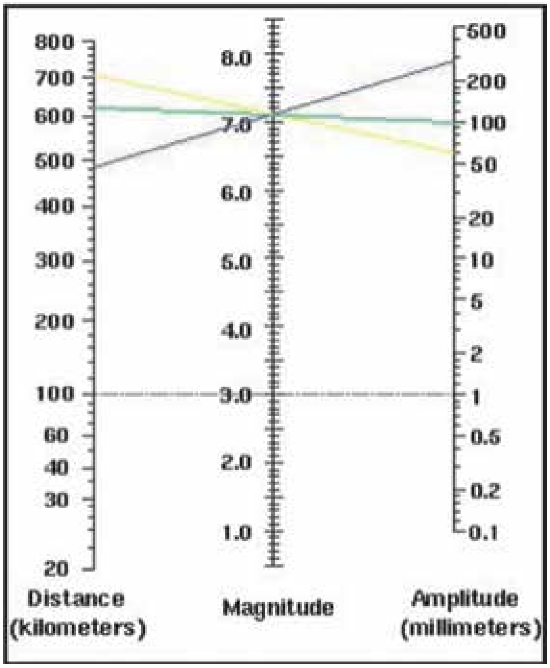
IMPLEMENTATION

– Measure the amplitude of the three seismograms provided to you at the previous part of the activity. As you can see, each tick on the seismograms corresponds to 50mm.
– Note the amplitude of each seismogram at the last column of your spreadsheet.
– Use the Richter nomogram (it would be optimal if you could print the nomogram from here):

i) For each seismogram, note the epicentral distance and the amplitude on the respective columns (left and right) of the nomogram.
ii) Connect the two points with a straight line. The line will intersect the middle column (earthquake magnitude).
iii) Repeat for the other two seismograms.

Now you will have three lines connecting the left and the right column. If your results are correct, then the three lines will meet at a specific point in the middle (magnitude) column. This is the Richter magnitude of your earthquake!

Note the magnitude of the earthquake at your notebook.
The magnitude of the earthquake described above can be found to be 7.1 according to the nomogram reading.



Analysis and Interpretation: Gather results from data
PART A - The Earthquake's Epicentre
Each group will present their epicentre location.

Compare your results and discuss with your classmates and your teacher any possible discrepancies.

What are the experimental uncertainties in your investigation?

Try to estimate the error in the epicentre's location.

Parameters that can affect the accuracy in determining the epicentre are:

a) The precision in finding the S-P time interval.
b) The precision in pinpointing every station on the map.
c) The precision in drawing the circles with the correct radius between the epicenter and each station.

The last two factors can be improved by optimizing the zoom options of the interactive map. When you draw the circles in order to find their intersection point, if you zoom in you will observe that the three circles don't coincide in one point, but instead a triangle is formed. If you draw a circle which will enclose the triangle within it, then we can assume that the circle's radius equals to the epicentre uncertainty, and its center is defined as the epicentre location.

The following discussion concerning the investigation of the parameter of depth can be omitted. However it is most relevant to the curriculum and requires the use of basic math and physics skills from the students.

During the hypothesis generation and design phase you solved a short exercise considering two waves of different speeds propagating at a straight line. Different observers were set at different distances from the wave source and recorded the time interval of each wave.

We found that the time interval between the two waves scales with the distance between the observer and the source.

Exactly the same method is applied for the determination of the earthquake's epicenter.

Discuss with your classmates and your teacher to evaluate the above statement.

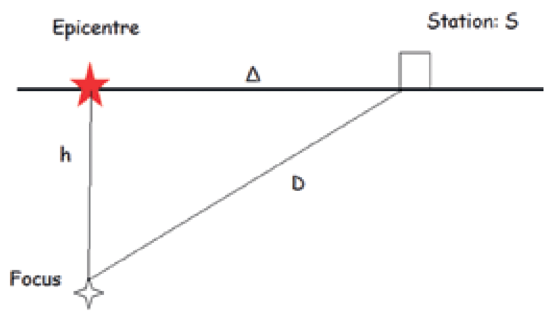
Investigation of the parameter of depth

Until now we have considered that the earthquakes are generated at zero or negligible depth compared to the epicentral distance.
Let's investigate the dependency of the arrival times on the depth of the earthquake.

We are assuming that the earth is uniform and thus that the S- and P- waves propagate in straight lines. Furthermore, the speeds of the S- and the P- waves are constant with respect to depth.

Assume that a station S is located at an epicentral distance Δ from the epicentre . The focus of the earthquake is found at a vertical distance h below the epicentre.

The focus and the station are separated by a distance equal to D.

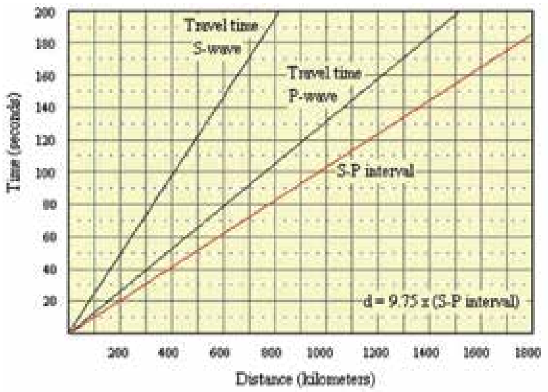


Assume that the S- and the P- waves originate from the focus and travel a straight distance equal to D until they reach the station.

The S- waves travel with Us = 3.5 km/s and the P- waves with Up = 7km/s. The S- waves reach the station at a time equal to Ts and the P- waves at a time equal to Tp.

a) Find a formula which will relate the distance D to the time difference : Ts-Tp.
b) Using the picture abve, find the relationship between D,Δ and h. (Hint: is the triangle orthogonal?)
c) Taking into account the two solutions above, find an expression for Ts-Tp with respect to h and Δ.
d) Assume an epicentral distance of Δ = 100 km and two depths : h1 = 10km and h2 = 30 km. What is the time difference Ts-Tp for each depth?
e) Check the following graph of the S-P time interval time difference vs epicentral distance and compare the time difference you calculated for the two depths to the time difference it provides for Δ=100km.

What do you observe?



The results seem inconsistent, but this happens because we compare a time-epicentral distance plot with time differences occuring when the depth of the earthquake is not negligible.

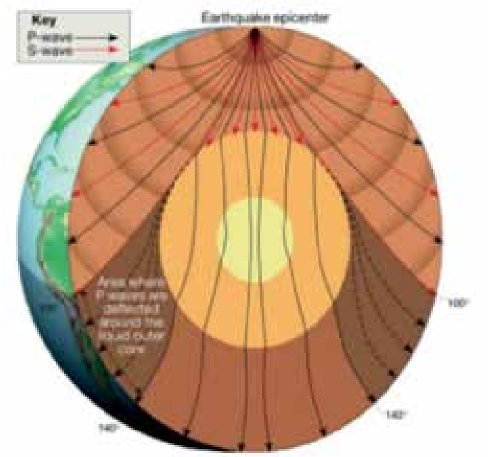
When seismologists deal with earthquakes of varying depth, they employ different methods in order to calculate the epicentric distances.

One of them is the Brunner method. For each depth there is a specific Time difference - epicentre distance curve which can be used to better interpret our data.

Considering the model of the depth we discuss here:

This is generally not the case because earth is not uniform and thus the speeds of the S- and P- waves differ with depth. As the depth Since the speeds differ, the seismic waves are diffracted and their paths are not generally linear. Furthermore, the S- waves are transverse and thus cannot penetrate the liquid core of the earth and are reflected. The model we discuss can be considered valid for shallow earthquakes, with short epicentral distances.

See the following picture for further insight:

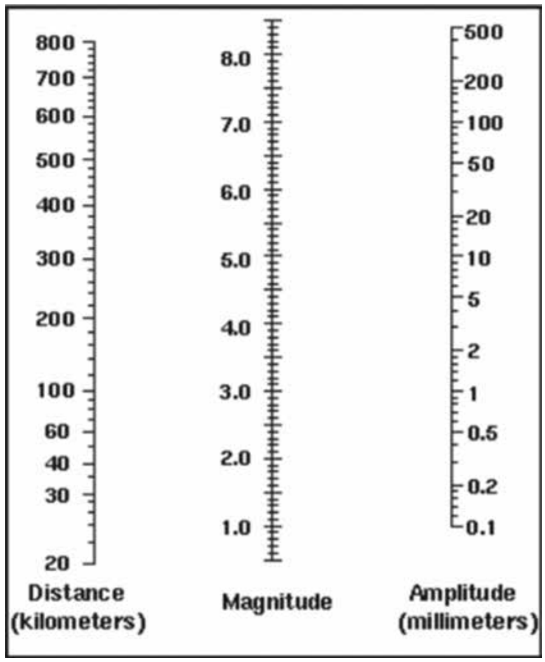


The next part of the analysis describes the investigation of the Richter nomogram and can be omitted if the time schedule is tight.

Part B - The Earthquake's Magnitude

The magnitude of the earthquake was estimated using a Richter nomogram with the amplitude and the epicentral distance as inputs.

Use the nomogram of the previous phase of your activity.



Magnitude vs Amplitude
Assume that the epicentric distance is equal to 100km.

Find the magnitudes M1,M2,M3 of an earthquake with amplitude equal to 1, 10 and 100 mm.

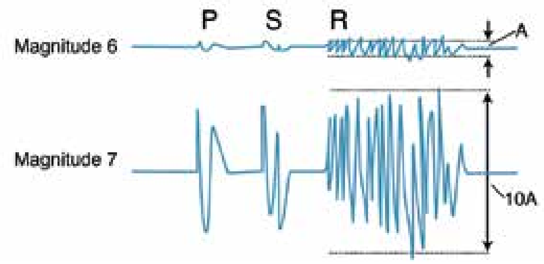
Discuss your findings.

How does the magnitude scale with amplitude?

How much higher amplitude does an earthquake of magnitude 6 have compared to a magnitude 4 earthquake?

Observe the following plot.

Does it agree with what you found?



Magnitude vs Distance
Now we will perform the same investigation now keeping amplitude a constant. Keep amplitude equal to A=100mm and draw a horizontal line passing from magnitude M = 7. This will lead to epicentral distance equal to 600km. Now do the same thing for A=100mm, and for various M, from 6 till 3. What do you observe? How does the magnitude change with distance if the amplitude is kept constant?

Students will observe that for the first part, the magnitude is increased by one unit when the amplitude is increased tenfold. This is the definition of a logarithmic scale.

The earthquake's magnitude can be calculated from the formula:

$$M = log_{10}\left(\frac{A}{Ao}\right)$$

assuming that the distance between seismograph and epicentre equals to 100km, and Ao = 0.001mm.

For two different earthquakes of amplitudes A1, A2 the logarithmic properties imply that:

$$M1 - M2 = log_{10}\left(\frac{A1}{Ao}\right) - log_{10}\left(\frac{A2}{Ao}\right) \rightarrow$$

$$M1 - M2 = log_{10}\left(\frac{\frac{A1}{Ao}}{\frac{A2}{Ao}}\right) \rightarrow$$

$$M1 - M2 = log_{10}\left(\frac{A1}{A2}\right)$$

Therefore if the 1st earthquake has 10 times the earthquake of the 2nd earthquake, its size will be one unit higher.

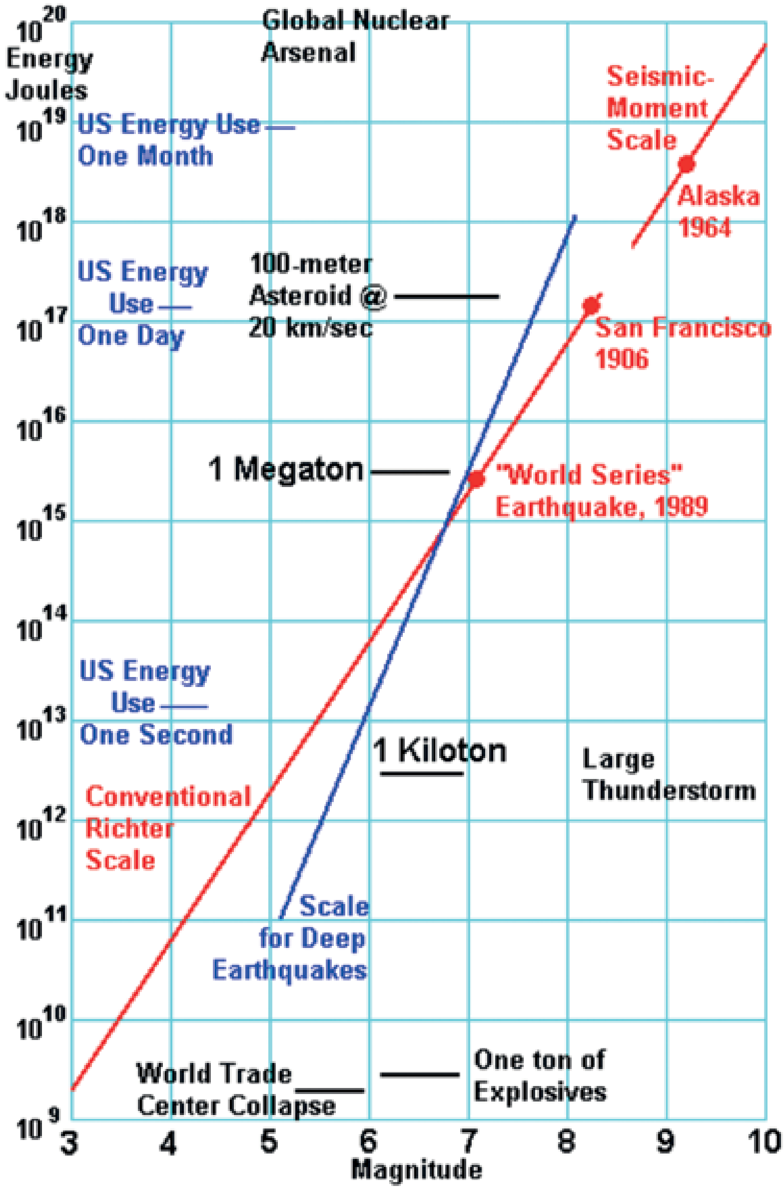
This part can be used in order to introduce (or refresh) the students' knowledge of logarithms.

For the second part, the magnitude increases by 1 unit when the distance is doubled in order to keep the same amplitude.

This means that the energy of the earthquake is higher since the surplus of energy compensates the energy loss of the waves during their travelling a greater distance.

Magnitude vs Energy
As we have discussed, the magnitude relates directly to the energy carried by the seismic waves. Every wave carries energy which depends on the amplitude and the frequency of the waves,the density of the earth, the propagation speed and the time it takes for the wave to travel from the focus to the station.

Observe the following plot:



The horizontal axis displays the earthquake magnitude whereas the vertical axis the energy of the earthquake measured in Joules.

– Use the value of the magnitude you measured in the investigation phase in order to find the energy of the earthquake you studied. Use the red line to map the magnitude into energy.

– If 1 g of TNT releases 4184 J of energy during its explosion, find the energy of the earthquake you studied in equivalent kilotones of explosive.

– Find the energy of an energy of magnitude equal to 5 and compare the values. How many times more energy does the earthquake you observed release in form of seismic waves? How would you interpret this result?

– What is the error in the energy calculation if I overestimate (or underestimate) the magnitude by 1 unit?

– Can you determine what will be the observable effects of an earthquake of the magnitude you observed?

The energy of an earthquake compared to its magnitude can be approximately given by the following formula:

$$log_{10}E = 1{,}5.M + 11{,}8$$

The resulting value of energy is measured in erg . In order to convert it in Joules you have to multiply by 10-7.

Our earthquake has M = 7.1, therefore E = 1015,46 J

Using the logarithmic identities again, we can find that if the magnitude of an earthquake increases by one unit, the energy increases 31,6 times. This implies that an earthquake of magnitude equal to 7 has approximately 1000 more energy than an earthquake of magnitude 5.

In other words, 1000 earthquakes with M=5 compare to an earthquake with M=7.

Conclude and communicate result/explanation
Observe the following video to review the technique of measuring the epicentre of an earthquake:

http://highered.mheducation.com/sites/dl/free/0073135151/90798/16_08.swf

Discuss possible differences between the technique proposed from the animation above and your method.

Do you consider the use of three stations as adequate in order to locate precisely the epicenter of the earthquake with the interactive map?

Evaluation/reflection
Each team will present their epicentre results and compare them with the real epicentre as it will be provided by the teacher.

Discuss the trilateration technique that you used in order to locate the epicentre.

If you have carried out the earthquake magnitude part of the activity present your magnitude-energy results too.

Discuss your overall results.

Do you believe that the job of a seismologist is easy? Is it interesting?

Topics for further discussion:

Safety during an earthquake
Once we know how catastrophic an earthquake can be for the environment, let's see what we should do in case an earthquake happens:

http://www.earthquakecountry.info/dropcoverholdon/

Check this video out and see how one should deal with earthquakes while they happen:

https://youtu.be/G57gCZGEPK0

Antiseismic buildings
To protect us from earthquakes, engineers have worked extensively in order to develop solutions for buildings resistant to the catastrophic forces of earthquakes. Look at the following videos and discuss:

https://youtu.be/sxpi9A7_syE
https://youtu.be/-N_Q6Q-3o7M

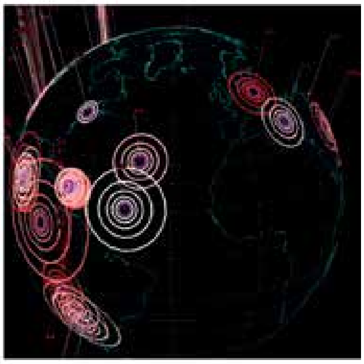
"Earthquakes and tectonic plates"

A lesson plan for junior high-school students (ages 12-14) in accordance with the Greek Science Curriculum

Introduction and orientation

(Provoke curiosity)

Observe carefully the following images:



Have you ever wondered what an earthquake is?

Have you ever experienced an earthquake?

Watch the following video of earthquakes happening all over the world:

http://video.nationalgeographic.com/video/earthquake-montage

Watch the following video on the Earthquake of San-Francisco in 1989:

http://www.history.com/topics/san-francisco/videos/mega-disasters-san-francisco-earthquake

Discuss your ideas concerning earthquakes.

How do you believe they are generated?

Define goals and/or questions from current knowledge

Definition:
An Earthquake is the shaking and vibration at the surface of the earth resulting from underground movement along a fault plane or from volcanic activity.

Earthquake Scales:
As we have seen, earthquakes can cause major destructions. In order to describe the severity of these destructions, scientists have invented the Richter and Mercalli scales.

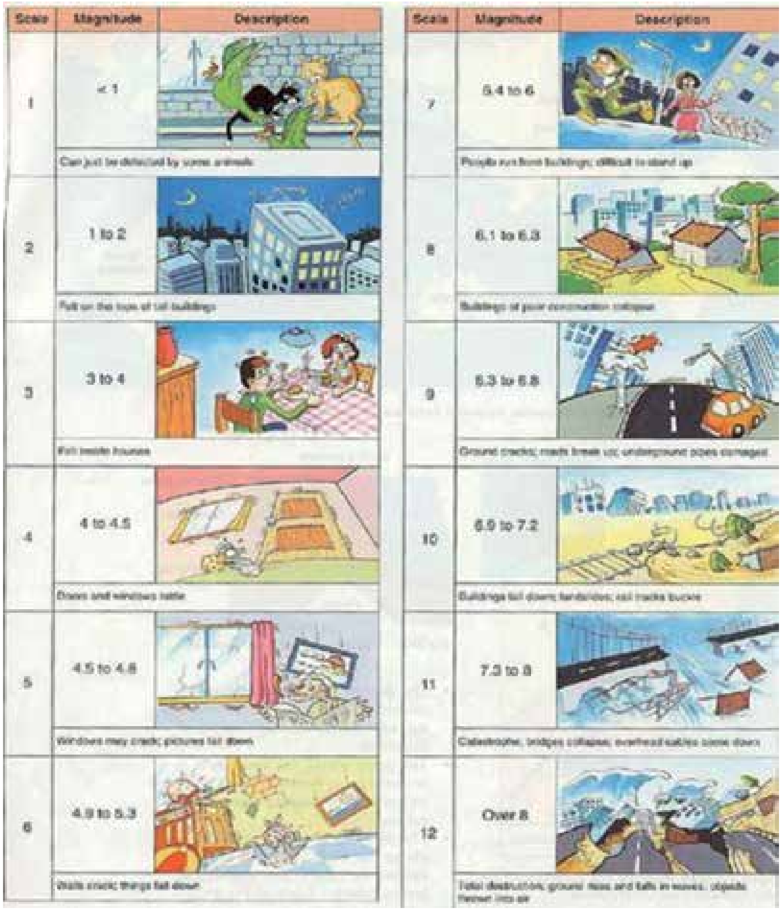
The **Richter magnitude scale** is a measure of the energy released by an earthquake. The earthquake magnitude M ranges from 1 to 10, with 1 being equal to the vibration of the earth when a train passes by. When earthquake A has one unit more magnitude than earthquake B, this means that A is 10 times stronger than B, or:

A releases 31.6 times more energy than B!!

The **Mercalli intensity scale** is a measure of the observed effects of an earthquake to both natural and human environment.

The value of the Mercalli scale depends on the distance from the epicentre of the earthquake (a.k.a its source) and on the structure of the ground.

Look at the picture below and discuss the relations between the Mercalli and the Richter scales. In the picture, the term: Scale refers to Mercalli and Magnitude to the Richter scale. ***Activity!***



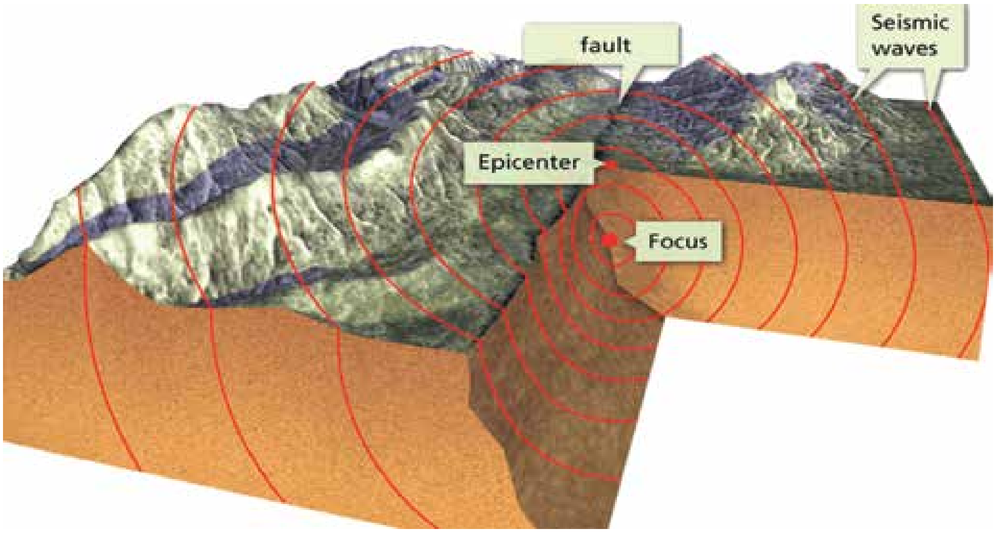
If you have experienced an earthquake try to find out what effects you observed on the Mercalli scale.

Then go to the previous picture and make an estimate of the Earthquake's magnitude in the Richter scale.

Compare your finding with the original reports from the news on the magnitude of the earthquake.

Was this method successful?

Fundamental Characteristics of Earthquakes
Observe the following picture: You can observe the seismic waves expanding from a source inside the earth.



This "source" of the seismic waves is the **Focus** (or hypocentre).

Now, let's draw a vertical line that starts from the focus and ends at the surface of the earth.

The length of the line is called the "**depth**" of the earthquake. The point on the surface of the earth exactly above the focus is called the "**epicentre".**

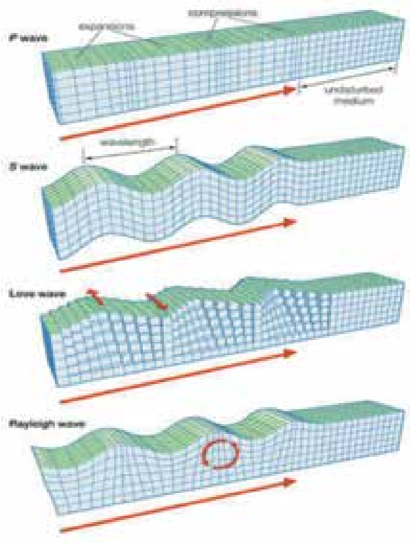
Earthquake waves travel through and on top of the surface of Earth carrying huge amounts of energy and causing the shaking and vibrations on the ground.
Earthquake waves can travel hundreds of kilometres causing earthquakes to be felt a long way away from the origin.

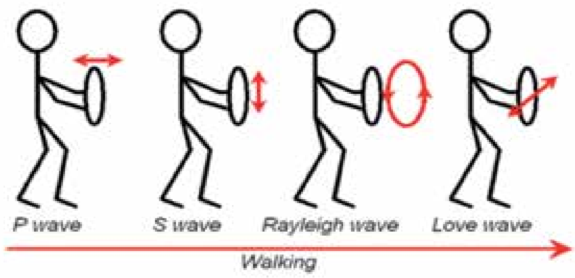
Types of Seismic Waves
There are several different kinds of seismic waves, and they all move in different ways. The two main types of waves are **body waves** and **surface waves**. Earthquakes radiate seismic energy as both body and surface waves.

Body waves have high frequency and can travel through the earth's inner layers. They are divided in two categories: The P- Waves (P: Primary), which arrive first, and the S-Waves (S: Secondary) which arrive after the P- Waves. This time difference between P- and S- waves is one of the most prominent characteristics which is taken into account when we detect earthquakes.

Surface Waves have lower frequency than the body waves and arrive after them during the earthquake. They can only move along the surface of the planet like ripples on water. Surface waves divide in Love waves and Rayleigh waves and are responsible for the majority of destruction taking place during an earthquake.

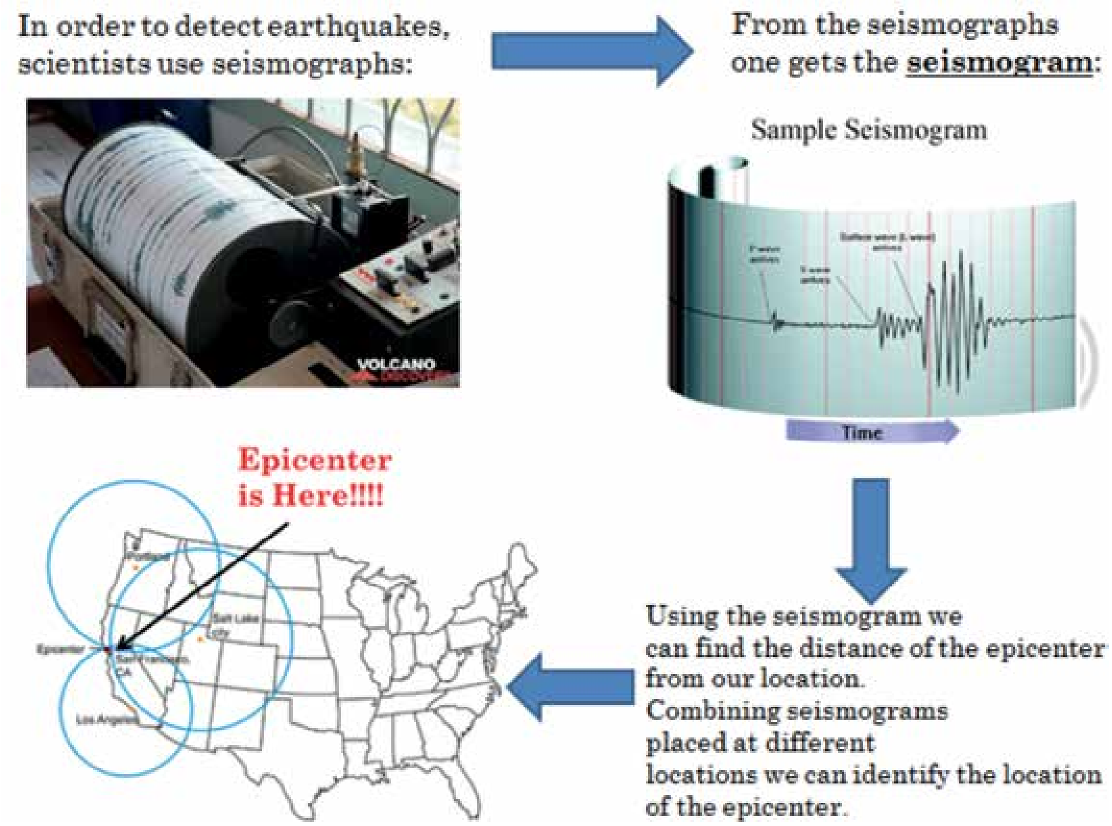
Look at the pictures below:





Can you describe the different kinds of motion that earth is being put into due to the different kinds of seismic waves? Can you replicate the waves using your body?

Detecting Earthquakes



Let's see how this is done:

This is how a seismogram is produced:
http://www.estium-concept.com/en/computer_graphics-geology_seismometerElect.htm

The seismogram can be used to find the epicentre distance from our station.

This is how we can locate the epicenter combining data from many stations:
http://www.estium-concept.com/en/computer_graphics-geology_epicenter.htm

General Remark: So far we have discussed the how's of the earthquake, but not the Why's. The basic definitions have been provided and a short overview of detection principles has been presented.

We have not given any leads as to why the earthquakes happen, as this is the body of the activity that will follow.

For more resources concerning the science behind earthquakes, you can visit the following link:
http://www.geo.mtu.edu/UPSeis/waves.html
http://authors.library.caltech.edu/51563/1/HKpt01.pdf

A more advanced activity for older students focusing on earthquake epicentre detection can be found here:
http://tools.inspiringscience.eu/delivery/view/index.html?id=0ab2173a003f40b48d1caf1639399aac&t=p

For further information concerning the earthquake epicenter detection, visit the following link:
https://www.youtube.com/watch?v=694yaY2ylTg

Generation of hypotheses or preliminary explanations

So far we have discussed the fundamental characteristics of earthquakes, but do we really know why earthquakes happen?

Suppose that you live in the middle of Siberia while a friend of yours lives in Italy or in Greece. Which of the two is more likely to experience an earthquake?

Back till the 60's, people knew that earthquakes and volcanoes tended to appear in certain parts of the world.

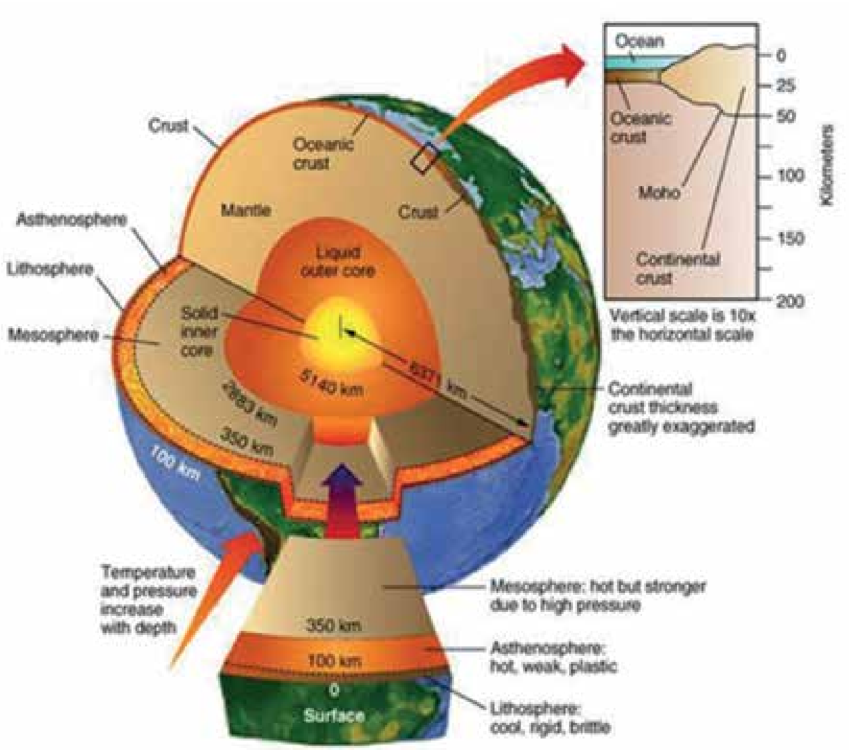
They knew for example the so called "ring of fire": a belt of going around the edge of the Pacific Ocean in which exist active volcanoes and there is strong seismic activity. The belt goes through New Zealand, Indonesia, Japan, Alaska and the North America.

On the contrary, places like Britain have neither active volcanoes nor strong seismic activity.

People assumed that the Earth's crust was ripped open along these "lines of weakness" for some reason allowing the molten rock from under the surface to pour out in volcanoes. The reasons for these cracks of the Earth were unknown. Maybe it was just chance. With this course of thought, a crack might appear anywhere in the world at any time creating volcanoes and producing seismic activity!

Discuss: What would you do in order to investigate the seismic activity with respect to geographic region?

Let's dive in the interior of the earth:



Discuss: Can you describe the interior of the earth? Observe the picture and think: Is the earth's interior uniform or does it have separate components? If so, can you name the components?

Of particular interest to us is the **Earth's Lithosphere**:

The lithosphere is the bedrock on which lay the earth's ocean (oceanic crust) and its continents (continental crust).

It is 50-100 km thick and manifests itself as the common ground between the upper mantle and the crust of the planet.

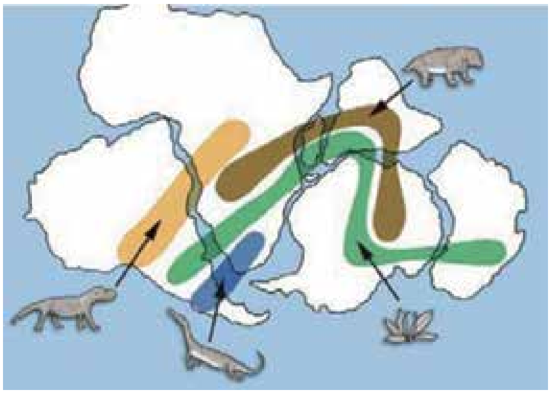
Without doubt, the earthquakes and the volcanic activity must be connected somehow with the structure of the lithosphere!!!

Let's check some clues coming from palaeontology:

Long research in this field has led the scientists with some striking conclusions. Let's summarize some of them:

- The shores of West Africa are very similar to the shores of South America
- Traces of Ancient vegetation existing in Africa were found in Europe
- Although there is no Volcanic action in Britain, volcanic rocks could be found in many regions, including North Wales and Scotland

Many observations like the one stated above, led the scientists to propose the theory of "Tectonic Plates".



There is too much material concerning the field of plate tectonics online, a great collection of which can be found here;
http://pubs.usgs.gov/gip/dynamic/dynamic.html

However, this educational activity mainly focuses on the key points of plate tectonics and the correlations with earthquakes so we will constrain ourselves and mainly outline the definitions.

Design/Model

According to the theory of tectonic plates, first developed by Wegener, the earth's lithosphere is not uniform. On the contrary, it is broken in many parts, the "plates" which slide on the top of the upper mantle.

The plates are constantly moving with respect to each other and colliding.

This theory explains among others the multitude of geographical and palaeontological results in terms of continental drift, according to which the earth's surface has been subject to constant change due to plate collisions and drift.

What about the earthquakes though?

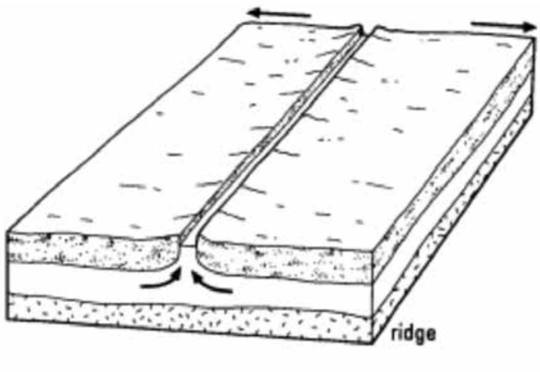
The Tectonic plate theory assumes that: very high tensions develop around the borders between plates and this is why Earthquakes happen!

Is this theory correct?

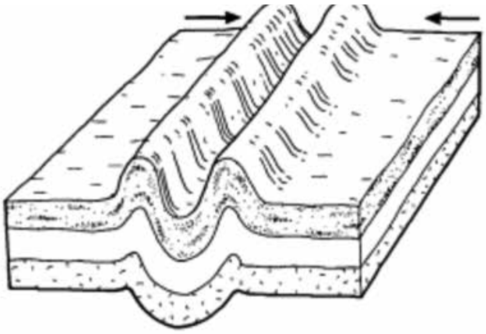
This is what we are about to find out in our activity!
You could use this material to stimulate further discussion with your students:

How do the tectonic plates collide?

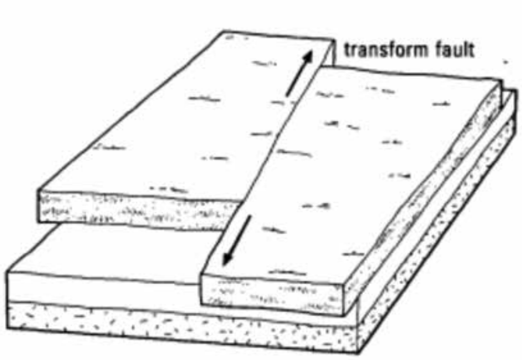
Where the plates drift apart from each other, a crack opens up allowing molten rock to flow out of volcanoes and fill the gap.



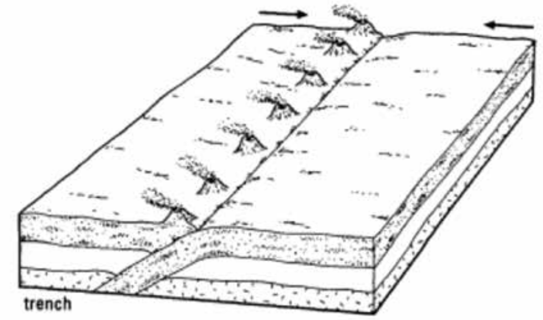
Sometimes the plates push up against each other, causing the rocks to buckle and fold up producing series of mountains. This is how the Alps and Himalaya were created!



In cases such as the San Andreas Fault in California, the tectonic theory supports that the plates push past each other as we can see below:



There are also cases such as the one illustrated below, that a plate is pushed below the surrounding plates and melts when it goes deep inside. This leads to extreme volcanic and earthquake activity and the creation of mountains as happens in Japan for example.

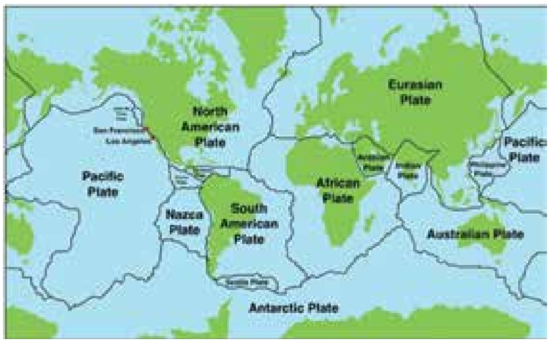


Plan investigation

In this part of your investigation, you will check the hypothesis of earthquake generation at the intersection lines of the lithospheric plates.

Look at the Map: You can see the lithospheric plates of the earth.

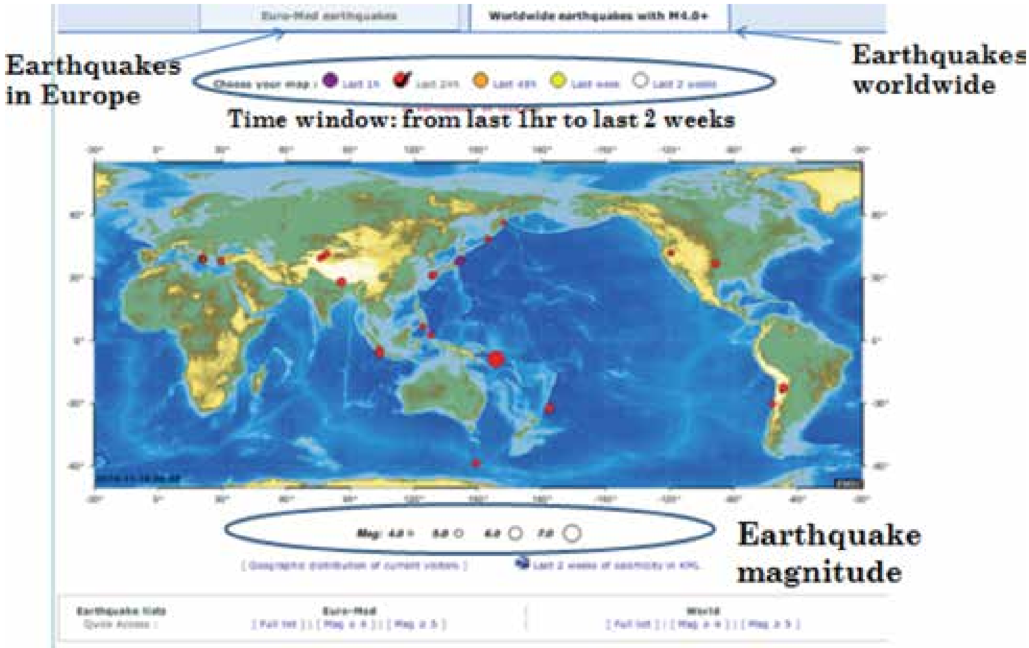
Try to find the countries where the lithospheric plates meet.



Name the countries that, according to the map on the previous slide, are expected to be more frequently subject to earthquakes.
What do you think about Australia, Russia, Philippines, Nepal, and Turkey?
Discuss with your classmates.

Perform investigation

Now, let's visit this link:
http://www.emsc-csem.org/#1w
Here we can see a list of earthquakes on an interactive map. The list is updated every hour. Each circle represents an earthquake.



- Start from the European map and observe the listed earthquakes. Choose your maps starting from the map which shows the earthquakes 1hr ago up to two weeks ago.
- You can click on each "circle" to see the exact magnitude, location, date and depth of the earthquake.
- Find the most seismic (with the highest rate of earthquakes) location in Europe. Find the magnitude of the strongest earthquake so far.
- Repeat the same steps for the world map.
- Now, shift the world map to the 2 weeks option.
- Observe the distribution of earthquakes.
- Compare your results with map 1 which presents the tectonic plates.

  Do you observe any correlation between the two maps?

  Discuss with your classmates.

Now, what do you think about Australia and Russia as compared to Philippines and Greece?

Can you explain the differences in seismicity between these countries?

Analysis and Interpretation: Gather result from data

Observe the Earthquake World Map from 1973-2008. Compare the map with the tectonic plate map in the previous section and with your findings from your investigation.

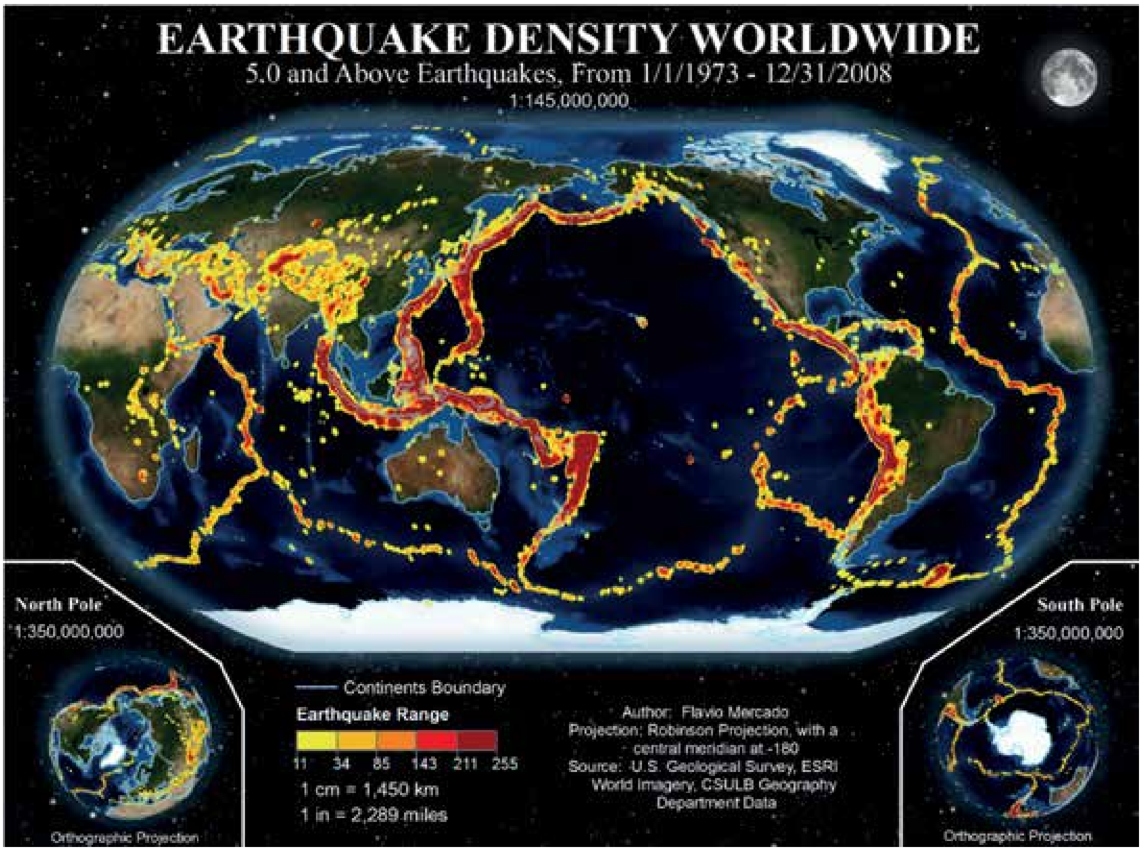
Is the theory of Earthquake generation due to plate collision at the boundaries between plates correct?

Conclude and communicate result/explanation

Have you been convinced about the validity of the tectonic plate theory?

As a project you can search online for evidence concerning the validity of the theory and its implications for other branches of science such as palaeontology.

Watch the following video to summarize what we have learnt so far:
https://www.youtube.com/watch?v=PwtFuG_M4EE



Evaluation/reflection
Discuss your findings and make a short presentation concerning the generation and distribution of earthquakes.

Which places on earth are in greater danger due to earthquakes?

Precaution and Safety During an Earthquake
Earthquakes are destructive, and most of the times unpredictable. In order to protect ourselves from them, there are specific measures that we must take, both as countries and as individuals:

Check the following video to see a test concerning an anti-seismic building:
https://youtu.be/-N_Q6Q-3o7M

Once we know how catastrophic an earthquake can be for the environment, let's see what we should do in case an earthquake happens:
http://www.earthquakecountry.info/dropcoverholdon/

Check this video out and see how one should deal with earthquakes while at school:
https://www.youtube.com/watch?v=bAHNhtRT50A

This part of the activity can be easily connected with precaution tests for earthquakes at your school.

"Σεισμοί - Χρόνος και Επίκεντρο"

Σύνδεσμος: http://graasp.eu/ils/575fab3cc3ddb608c844d2e0/?lang=el

Introduction:
Online interactive educational activities about earthquakes for junior high school (12-15 years old) or/and high school (15-18 years old) students following the Greek science curriculum.

The two activities documented below in Greek are complementary and can be done by individuals or per group of students. The first activity is entitled "Earthquakes – Time and Epicenter", and the second one "Earthquakes – Timer Activity". Their online links are:

http://graasp.eu/ils/575fab3cc3ddb608c844d2e0/?lang=el
http://graasp.eu/ils/575fab50c3ddb608c844d2e1/?lang=el

In the former activity, "Earthquakes – Time and Epicenter", the main objective is for students to understand that everyday a lot of earthquakes happen in the region of Greece. Scientists have developed automatic algorithms to process the data from the various seismographic stations to measure the main parameters of each earthquake. Following the lesson's steps students will follow the same procedure to find the epicenter of an earthquake by measuring the difference of time of arrival of the seismic waves.

In the complementary educational activity, "Earthquakes – Timer Activity", they can better investigate and understand the relation between the traveling distance and the time interval of arrival.

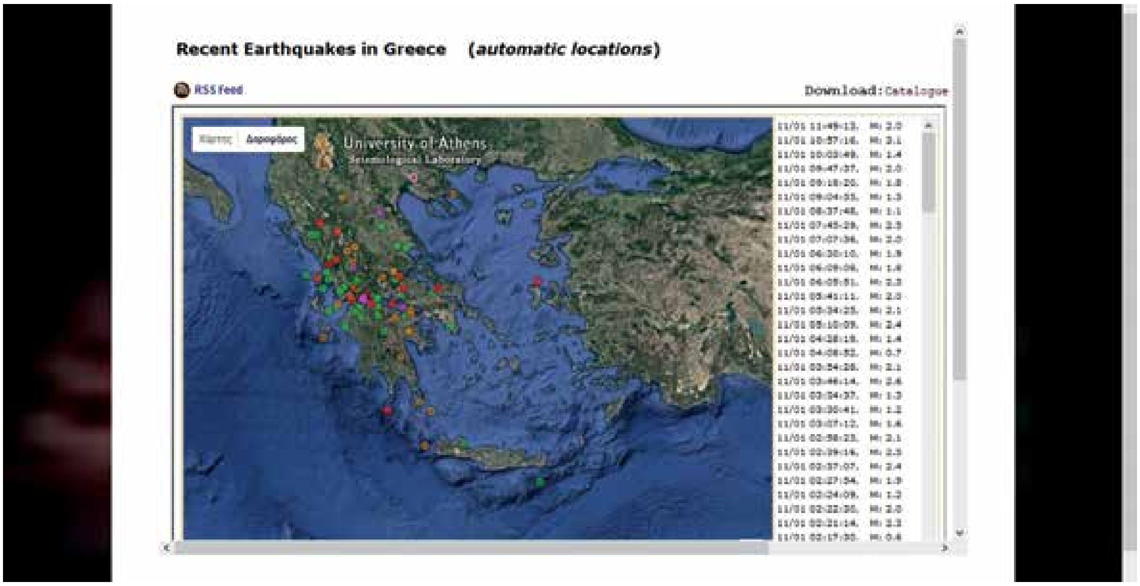
Each activity can be implemented in the classroom separately or both in combination, and may conclude with the two short videos about the precaution and civil protection measures and actions during an earthquake.

Διαδραστικό μάθημα για μαθητές γυμνασίου/λυκείου

Εισαγωγή

Παρακάτω βλέπετε ένα χάρτη με του σεισμούς που έγιναν πρόσφατα στην Ελλάδα. Καθημερινά αρκετοί σεισμοί γίνονται στον ελλαδικό χώρο. Οι επιστήμονες και ερευνητές έχουν αναπτύξει αλγόριθμους για να αναλύονται αυτόματα τα δεδομένα που καταγράφονται από τους διάφορους σεισμομετρικούς σταθμούς και να μετρούν τα χαρακτηριστικά του κάθε σεισμού.

Σε αυτό το μάθημα θα εφαρμόσουμε παρόμοια διαδικασία, ώστε να βρούμε το επίκεντρο ενός σεισμού.



Πριν ξεκινήσουμε ας σκεφτούμε το εξής ερώτημα.

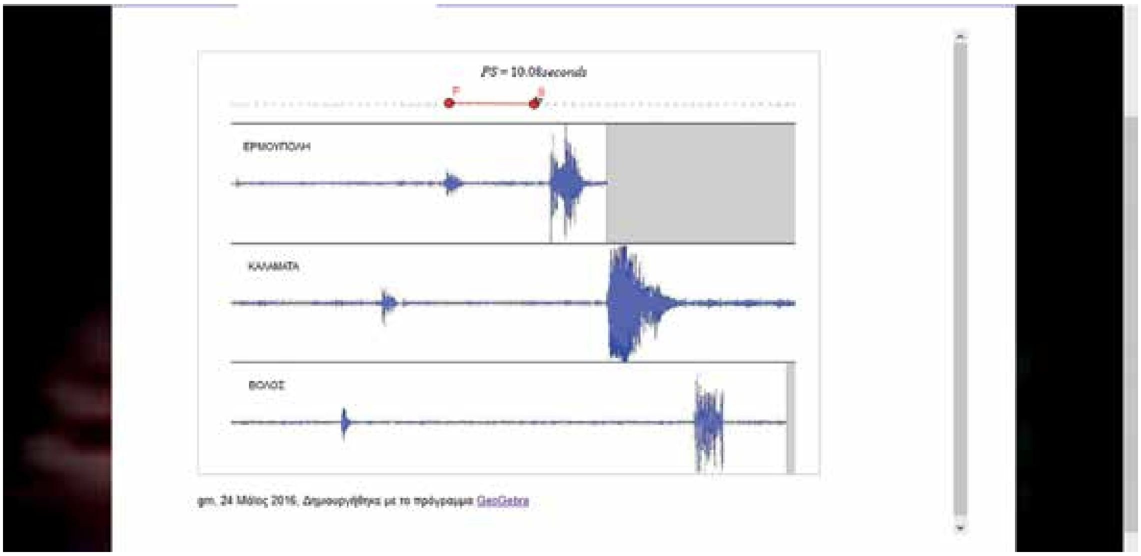
Πόσους σεισμομετρικούς σταθμούς πιστεύετε ότι χρειαζόμαστε για να βρούμε το επίκεντρο ενός σεισμού;

Γράψτε παρακάτω την απάντηση σας.

Χρόνος και Απόσταση

Όταν συμβαίνει ένας σεισμός δημιουργούνται σεισμικά κύματα τα οποία μεταφέρουν τη δόνηση του εδάφους. Όταν τα σεισμικά κύματα φτάσουν σε ένα σεισμομετρικό σταθμό ή σεισμόμετρο τότε καταγράφονται δύο κύρια σήματα τα οποία προέρχονται από το «Πρωτεύον» και «Δευτερεύον» σεισμικό κύμα. Το «Πρωτεύον» κύμα φτάνει και καταγράφεται πρώτα και στη συνέχεια το «Δευτερεύον». Μετρώντας τη διαφορά χρόνου μεταξύ των δύο σημάτων όπως καταγράφονται από διάφορους σταθμούς μπορούμε να βρούμε το επίκεντρο του σεισμού.

Παρακάτω βλέπετε τρία σεισμογράμματα όπως καταγράφηκαν από τρεις διαφορετικούς σταθμούς. Για κάθε σεισμόγραμμα μετακινείστε τα σημεία P και S και βρείτε το χρόνο που μεσολαβεί μεταξύ των δύο σημάτων σε δευτερόλεπτα. Αυτός ο χρόνος ονομάζεται διαφορά χρόνου άφιξης.



Γράψτε παρακάτω τους χρόνους (δηλ. τις διαφορές χρόνου άφιξης) που βρήκατε για τους τρεις σταθμούς. Πολλαπλασιάζοντας τον κάθε χρόνο με 7,5 χιλιόμετρα ανά δευτερόλεπτο βρίσκουμε την απόσταση που έγινε ο σεισμός από τον κάθε σταθμό. Γράψτε παρακάτω τις αποστάσεις που βρήκατε.

____

____

____

[Προαιρετικά]

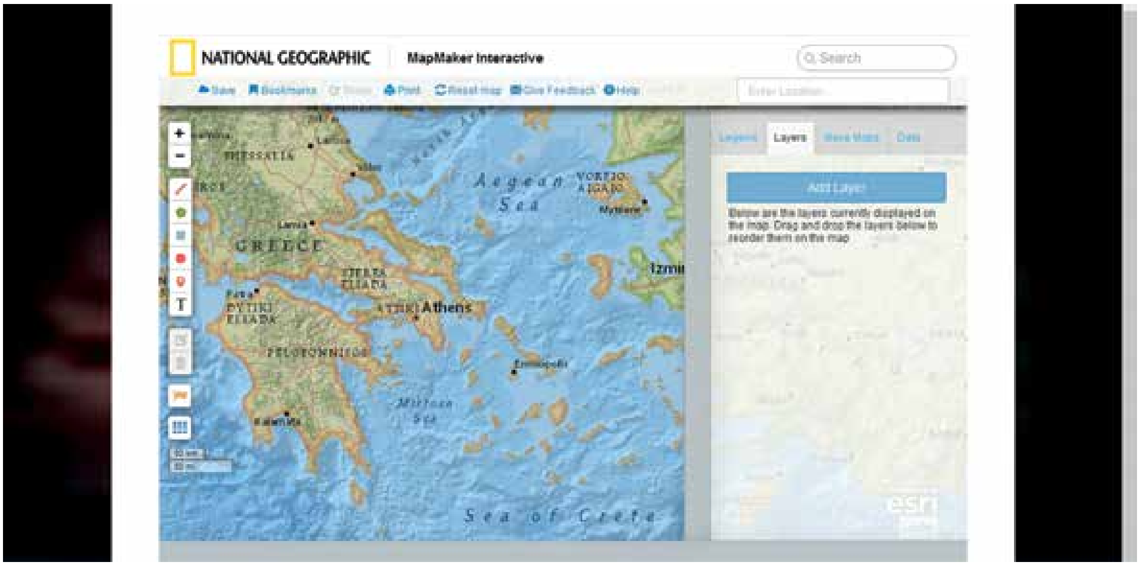
Για να κατανοήσουμε καλύτερα πώς από τη χρονική διαφορά άφιξης και καταγραφής των δύο σημάτων σε ένα σεισμόμετρο μπορούμε να βρούμε την απόσταση από την οποία προήλθαν τα σεισμικά κύματα θα κάνουμε μια απλή δραστηριότητα. Πατήστε εδώ για να μεταβείτε στη Δραστηριότητα Χρονομέτρησης

Επίκεντρο

Με τη βοήθεια του παρακάτω διαδραστικού χάρτη κάντε τα εξής:

1. Αρχικά βρείτε τη θέση των τριών σεισμομετρικών σταθμών
2. Για κάθε σταθμό σχεδιάστε κύκλο που να έχει κέντρο τον σταθμό και ακτίνα όση η απόσταση που βρήκατε
3. Το σημείο ή η περιοχή όπου οι τρεις κύκλοι τέμνονται είναι το επίκεντρο του σεισμού

(Σημείωση: σε περίπτωση που δεν εμφανίζεται σωστά ο διαδραστικός χάρτης προσπαθήστε να μεταβείτε σε αυτό το σύνδεσμο)



Συμπέρασμα

Πού βρίσκεται το επίκεντρο του σεισμού; Γράψτε παρακάτω την απάντηση σας.

Πόσους σεισμομετρικούς σταθμούς χρειαζόμαστε τουλάχιστον για να εντοπίσουμε το επίκεντρο ενός σεισμού; Γράψτε παρακάτω την απάντηση σας.

Συζήτηση

Παρακολουθείστε τα παρακάτω βίντεο σχετικά με τα μέτρα προστασίας σε περίπτωση σεισμού. Συζητείστε με τους συμμαθητές σας τι πρέπει να κάνουν στην τάξη ή στο σπίτι σε περίπτωση σεισμού.

Πληροφορίες

Αυτή η διαδραστική εκπαιδευτική δραστηριότητα σχεδιάστηκε από τον Δρ. Γεώργιο Μαυρομανωλάκη (email: gmavroma@ea.gr) στο πλαίσιο του ευρωπαϊκού έργου «Schools Study Earthquakes» του προγράμματος Erasmus+

“Σεισμοί - Δραστηριότητα Χρονομέτρησης”

Σύνδεσμος:
http://graasp.eu/ils/575fab50c3ddb608c844d2e1/?lang=el

Εισαγωγή
Σε αυτή τη δραστηριότητα θα κατανοήσουμε καλύτερα τη σχέση μεταξύ της απόστασης και της διαφοράς χρόνου άφιξης

Υπόθεση
Με το σεισμόμετρο μετράμε τη διαφορά χρόνου άφιξης του Πρωτεύοντος και Δευτερεύοντος σεισμικού κύματος που προέρχεται από το σεισμό. Και τα δύο σεισμικά κύματα διανύουν την ίδια απόσταση από το σημείο που έγινε ο σεισμός μέχρι το σεισμόμετρο.

Δε γνωρίζουμε αυτή την απόσταση. Και επίσης δε γνωρίζουμε πότε ακριβώς συνέβει ο σεισμός. Οπότε δε μπορούμε να μετρήσουμε πόσο χρόνο έκανε το κάθε σεισμικό κύμα να φτάσει στο σεισμόμετρο.

Αυτό που μετράμε με το σεισμόμετρο είναι η διαφορά χρόνου άφιξης των δύο κυμάτων.

Αν επιπλέον γνωρίζουμε την ταχύτητα με την οποία ταξιδεύει το κάθε σεισμικό κύμα τότε μπορούμε να υπολογίσουμε την απόσταση που διένυσαν για να φτάσουν στο σεισμόμετρο.

Στο επόμενο βήμα θα διερευνήσουμε αυτή την υπόθεση εργασίας χρησιμοποιώντας ένα απλό παράδειγμα.

Διερεύνηση
Στην παρακάτω διαδραστική εφαρμογή βλέπουμε τους δρομείς A και B οι οποίοι ξεκινούν από την γραμμή έναρξης και τρέχουν προς τη γραμμή χρονομέτρησης.

Οι δρομείς ξεκινούν μαζί και τρέχουν με γνωστή ταχύτητα που δεν αλλάζει.

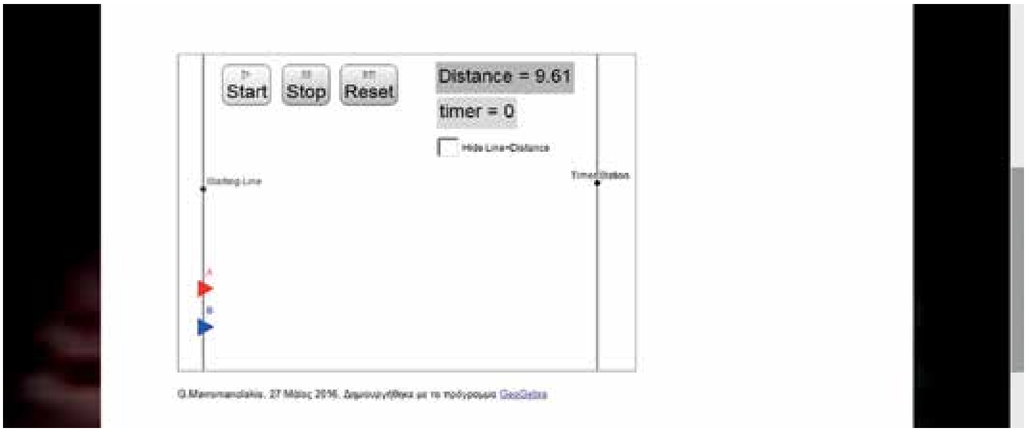
Ο χρονομέτρης ξεκινάει τη χρονομέτρηση μόνο όταν ο δρομέας Α περνάει τη γραμμή.

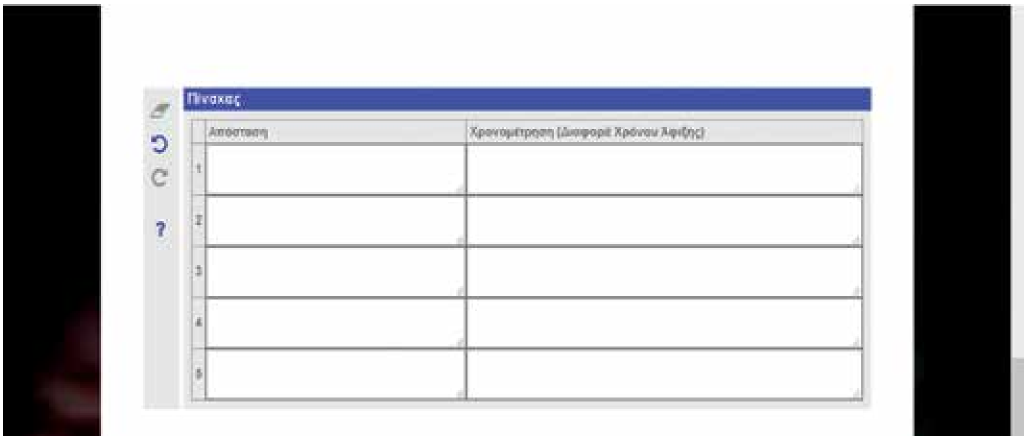
Πατήστε το κουμπί έναρξης για να δείτε πότε ξεκινάει η χρονομέτρηση.

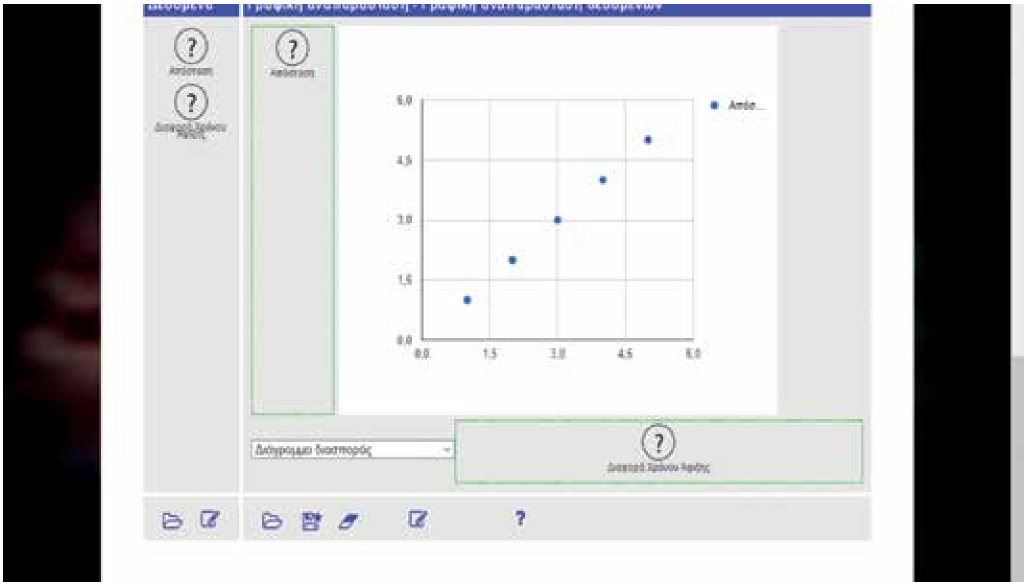
Στη συνέχεια κάντε τα εξής:

Βήμα 1
– Μετακινείστε τις γραμμές έναρξης ή/και χρονομετρητή για να αλλάξετε την μεταξύ τους απόσταση
– Για να μετρήσετε τη διαφορά χρόνου άφιξης των δρομέων A και B πατήστε Stop όταν ο δρομέας B φτάσει στη γραμμή χρονομέτρησης.
– Κάντε το ίδιο για διάφορες αποστάσεις. Στον παρακάτω πίνακα γράψτε τις τιμές της απόστασης και της χρονομέτρησης.
– Κάντε γραφική παράσταση με τις μετρήσεις σας.

Βήμα 2
– Επιλέξτε «Hide Line+Distance» ώστε να μην εμφανίζεται η γραμμή έναρξης και η απόσταση.
– Μετακινείστε τη γραμμή χρονομέτρησης σε νέα θέση.
– Πατήστε το κουμπί έναρξης.
– Πατήστε Stop όταν ο δρομέας B φτάσει στη γραμμή.
– Τώρα γνωρίζετε τη διαφορά χρόνου άφιξης των δύο δρομέων αλλά δε γνωρίζετε την απόσταση που διένυσαν. Για να βρείτε την απόσταση θα χρησιμοποιήσετε τη γραφική παράσταση που κάνατε στο Βήμα 1. Για τη διαφορά χρόνου άφιξης δείτε ποια απόσταση αντιστοιχεί.
– Ελέγξτε αν αυτό που βρήκατε είναι σωστό επανεπιλέγοντας «Hide Line+Distance»


Start
Stop
Reset
Distance = 9.61
timer = 0


Πίνακας
1
2
3
4
5


6,0
4,5
3,0
1,5
0,0
0,0
1,5
3,0
4,5
6,0

Συμπέρασμα

Διερευνήσαμε την παρακάτω υπόθεση:

Εάν μπορούμε να μετρήσουμε τη διαφορά χρόνου άφιξης του πρωτεύοντος και δευτερεύοντος σεισμικού κύματος ΚΑΙ γνωρίζουμε την ταχύτητα τους τότε μπορούμε να υπολογίσουμε την απόσταση μεταξύ του επίκεντρου του σεισμού και του σεισμόμετρου.

Είναι η υπόθεση αυτή σωστή ή λάθος; Τι βρήκαμε στη φάση της διερεύνησης;

Γράψτε την απάντηση σας παρακάτω.

Με βάση τη δραστηριότητα που κάνατε γράψτε παρακάτω σε τι αντιστοιχεί η κάθε μία από τις παρακάτω έννοιες: 1. χρονομετρητής, 2. δρομέας Α, 3. δρομέας Β, 4. απόσταση, 5 διαφορά χρόνου άφιξης δρομέων, όταν αναφερόμαστε σε σεισμούς.

Συζήτηση

Συζητείστε με τους συμμαθητές σας τα βήματα που κάνατε σε αυτή την δραστηριότητα. Ποια είναι τα κύρια βήματα που κάνατε;

Γράψτε την απάντηση σας παρακάτω.

Πληροφορίες

Αυτή η διαδραστική εκπαιδευτική δραστηριότητα σχεδιάστηκε από τον Δρ. Γεώργιο Μαυρομανωλάκη (email: gmavroma@ea.gr) στο πλαίσιο του ευρωπαϊκού έργου «Schools Study Earthquakes» του προγράμματος Erasmus+ .

4. Evaluation of the SSE project

The SSE project will use two different questionnaires to see project's impact on the students and teachers who participate to the project implementation phase.

The first questionnaire concerns students' perception about their science classes. With this questionnaire, it is intended to collect data from students about perception of their science classes, like their motivation for science at school, their self confidence in their own abilities in science at school, what they get out of science at school, their perception of the necessity of science education etc. It is a well-known issue that aspects like self-confidence, attitudes, interest and motivation are key factors associated with teaching and learning of science in formal and informal education. The pre and post responses from students that will be collected from Greece, Cyprus, Italy, Bulgaria and Turkey will shed a light on the explanations of how students' perceptions about their science classes changes from the project activities. In order to collect data from students, ROSE Project's questionnaire "my science classes" will be used. The questionnaire includes 16 items, each with a 4-point Likert scale from "Disagree" to "Agree" (Schreiner, Sjøberg, 2004). The questionnaire can be found in the Appendix 1.

The second questionnaire is designed to collect data from the teachers. It seems that there is a need to clarify teachers' preferences related to their use of inquiry-based science education in classroom. In order to enact teaching science as inquiry, the teacher is required to develop approaches that situate learning in authentic problems, model actions of scientists in guiding and facilitating students to make sense of data and support students in developing their personal understandings of science concepts (Crawford, 2007). The complexity of teaching science as inquiry in a K-12 school setting and the demands on a teacher to take on a myriad of roles may be important reasons why this kind of teaching is so rare (Crawford, 2007). The main aim of using this questionnaire is to determine science teachers' usage of inquiry-based science education in their classroom before and after project implementation phase. The data which will be collected from science teachers is expected to give further insights for designing and re-constructing better teaching strategies and learning environment orientations. The instrument consists of two parts: The first part, which includes 4 questions, focuses on the demographic information about science teachers including gender, grade level, teaching subject and length of science teaching experience. The second part of the questionnaire includes 27 items. The subjects were asked to respond using a five-point scale (from almost never to almost always). The score 1 represented the option "almost never" while score 5 on the scale represented the category "almost always". All of the items were positively written. The questionnaire can be found at the Appendix 2 (Cavas, Holbrook, Kask, Rannikmae, 2013).

5. References

Cavas, B., Holbrook, J., Kask, K., Rannikmae, M. (2013) "Development of an Instrument to Determine Science Teachers' Implementation of Inquiry Based Science Education in their Classrooms" International Journal of Primary Education. 2(2), 9-22.

Crawford (2007). Learning to Teach Science as Inquiry in the Rough and Tumble of Practice. Journal of Research in Science Teaching. 44(4), 613–642.

Schreiner, C., Sjøberg, S. (2004). Sowing the seeds of ROSE. Background, Rationale, Questionnaire Development and Data Collection for ROSE (The Relevance of Science Education) – a comparative study of students' views of science and science education (pdf) (Acta Didactica 4/2004). Oslo: Dept. of Teacher Education and School Development, University of Oslo.

APPENDIX 1

My science classes

To what extent do you agree with the following statements about the science that you may have had at school?

(Give your answer with a tick on each line. If you do not understand, leave the line blank.)

	Disagree		Agree	
1. School science is a difficult subject	☐	☐	☐	☐
2. School science is interesting	☐	☐	☐	☐
3. School science is rather easy for me to learn	☐	☐	☐	☐
4. School science has opened my eyes to new and exciting jobs	☐	☐	☐	☐
5. I like school science better than most other subjects	☐	☐	☐	☐
6. I think everybody should learn science at school	☐	☐	☐	☐
7. The things that I learn in science at school will be helpful in my everyday life	☐	☐	☐	☐
8. I think that the science I learn at school will improve my career chances	☐	☐	☐	☐
9. School science has made me more critical and sceptical	☐	☐	☐	☐
10. School science has increased my curiosity about things we cannot yet explain	☐	☐	☐	☐
11. School science has increased my appreciation of nature	☐	☐	☐	☐
12. School science has shown me the importance of science for our way of living	☐	☐	☐	☐
13. School science has taught me how to take better care of my health	☐	☐	☐	☐
14. I would like to become a scientist	☐	☐	☐	☐
15. I would like to have as much science as possible at school	☐	☐	☐	☐
16. I would like to get a job in technology	☐	☐	☐	☐

APPENDIX 2

You don't do this every day...

Please help us to improve teacher pre and in service teacher programs and students' learning in science and technology by filling this questionnaire. Teachers put emphasis on different aspects of students learning. This questionnaire seeks to establish current teacher preferences in the teaching of science subjects at a particular grade level and also the teachers' perceptions of students' expectations. Please can you answer the questions which are very crucial for us to understand your preferences. It will take you approximately 15 minutes to complete this survey. Please note that we will keep your response confidential and the results will be used only scientific purposes. If you have any question regarding this questionnaire, you can contact us using details at the end of this letter. Thanks for your help in advance.

Part A: About you

Gender	Female ○	Male ○					
Grade level of your teaching	6th ○	7th ○	8th ○	9th ○	10th ○	11th ○	12th ○
Teaching subject	Physics ○	Chemistry ○	Biology ○	Primary science ○			
Teaching experience	1-5 years ○	6-10 years ○	11-15 years ○	15-20 years ○	More than 20 years ○		

Part B. About your teaching preferences

Please select the response that best describes your teaching with respect to the grade and the subject indicated in Part A section

ABOUT YOUR TEACHING	Almost never			Almost always	
1. I guide my students to use experimental data to explore patterns leading to conclusions	①	②	③	④	⑤
2. My students and I discuss and create scientific questions together which my students then attempt to answer	①	②	③	④	⑤
3. I give my students step by step instructions to allow them to develop conclusions from their investigations	①	②	③	④	⑤
4. I guide my students to consider their scientific results when making decisions on socio-scientific issues	①	②	③	④	⑤
5. My students use data to develop patterns and draw conclusions by themselves	①	②	③	④	⑤
6. I give my students step-by-step instructions so that they can conduct investigations	①	②	③	④	⑤
7. I guide my students on identifying the variables to be controlled in an investigation	①	②	③	④	⑤
8. I help my students to develop hypotheses about the solution to a scientific problem	①	②	③	④	⑤

9. I guide my students to think about the relevant literature and other resources they need to find to develop their investigations	①	②	③	④	⑤
10. My students design their own procedures for undertaking studies	①	②	③	④	⑤
11. My students develop their own conclusions from their investigations	①	②	③	④	⑤
12. My students determine which data to collect for their investigations	①	②	③	④	⑤
13. My students propose and use scientific evidence to evaluate risks such as those related to environmental or health related issues	①	②	③	④	⑤
14. I guide my students on how to collect data to solve a scientific problem	①	②	③	④	⑤
15. I tell my students the variables they need to control in undertaking their investigations	①	②	③	④	⑤
16. I provide my students with the relevant literature and other resources to develop their plans for investigations	①	②	③	④	⑤
17. My students are given opportunities to develop their own hypotheses aligned with scientific questions	①	②	③	④	⑤
18. I give my students step-by-step instructions for obtaining data/making observations	①	②	③	④	⑤
19. I provide my students with a hypothesis which the students test through investigations	①	②	③	④	⑤
20. My students are given opportunities to create scientific questions as part of teaching	①	②	③	④	⑤
21. I undertake to interpret the data collected by my students and ask them to make a record	①	②	③	④	⑤
22. I guide my students to plan investigation procedures	①	②	③	④	⑤
23. I guide my students to develop conclusions to scientific evidence	①	②	③	④	⑤
24. I supply scientific questions to be answered by my students	①	②	③	④	⑤
25. My students find related literature and resources by themselves to develop their investigations	①	②	③	④	⑤
26. My students identify the variables that they need to control in carrying out investigations	①	②	③	④	⑤
27. I provide guidelines for students to relate the results of their investigations to make decisions about socio-scientific issues	①	②	③	④	⑤

Seismology Handbook

Preface

The main purpose of educational systems is acquisition of knowledge. One of the most effective ways to achieve this is by triggering learners' interest. Consequently, this triggering becomes a need. In natural sciences, it is observed that students become enthusiastic and respond better during the learning process when experimental techniques, through both physical and/or virtual means, are employed. And for this employment seismology presents itself as an excellent candidate.

Seismology is fundamental for understanding our dynamic planet, as it plays a vital role in monitoring both human-made and natural seismogenic events. Appreciating and understanding seismology's scientific and societal relevance requires knowledge of geology and physics, often coupled with elements of civil engineering, environmental sciences, official state policy, geography and geo-engineering as well as other scientific disciplines. Seismology is thus an engaging and quantitative science exhibiting a number of inherent links to wider areas of science but also to society providing the opportunity for applying multi-field scientific hands on experimental as well as theoretical activities.

Seismology in school education can promote scientific literacy at all levels but its benefits go far wider than simply providing scientific knowledge about this everyday natural phenomenon. It provides the basis for informed action to protect lives and property on local, regional, and national levels. As such, the SSE project and proposed approach will not only contribute to providing high-level educational material to teachers and their students but will also highlight aspects of civil protection, citizenship, civil responsibility and cooperation.

Teachers guide

The main purpose of this guide is to step by step direct teachers in organizing a training route which would ultimately lead to the active students' participation in seismograph handling process, recording and studying seismograms, calculating seismic parameters and exchanging results and experience within their cooperation with other student groups participating in the project.

STEP 1

Teachers should give pupils an incentive to the process in which they will participate so that they understand the need for dealing with the study of the seismicity of the country they live in. The teacher has to motivate them by providing initial information on earthquakes (e.g. how they are created) and encourage them to seek more information online, in printed form or by contacting scientists specialized on this subject. Some introductory information concerning the origin of earthquakes and the propagation of the seismic wave is presented below.

Earthquake Definition

An earthquake is a shaking of the ground. This could be due to the sudden breaking and movement of rock within the earth's outermost crust (i.e tectonic plate relative movements) but also due to explosions. The edges of the shifting masses are marked by faults, which are breaks in the continuity of a body rock. Most earthquakes occur along the fault lines when the tectonic plates slide past each other or collide against each other. The shifting masses send out seismic waves that may be powerful enough to alter the surface of the Earth, opening cracks in the ground, cause volcanic eruptions, tsunamis and great damage in human-made structures.

Seismic waves

They are waves of energy produced by the change in volume or shape of the medium and are travelling through the earth and recorded on seismographs. They are emitted from the seismic source to all directions and propagate with speeds depending on the elastic properties and density of the rocky crust.

There are several different kinds of seismic waves but the two main types are **body waves** and **surface waves**. Body waves can travel through the earth's inner layers, but surface waves can only move along the surface of the earth's crust. Either body or surface waves radiate seismic energy.

1. Body waves

They are emitted from the seismic source and by traveling through the inner layers of the crust body waves arrive before surface waves which are also emitted by an earthquake. The frequency of body waves is higher than the frequency of surface waves. Body waves are created at the seismic source and the two main types are the longitudinal primary waves (P-waves) and the transverse secondary waves (S-waves).

P-waves travel at higher speeds than the S-waves and thus arrive first at the seismic station and are recorded first on seismographs. P waves are also known as **compressional waves**, because of the pushing and pulling they do. Subjected to a P wave, particles move in the same direction that the wave is moving in, which is the direction that the energy is traveling in, and is sometimes called the 'direction of wave propagation' while S waves move rock particles up and down, or side-to-side--perpendicular to the direction of wave propagation. (Figure 1).

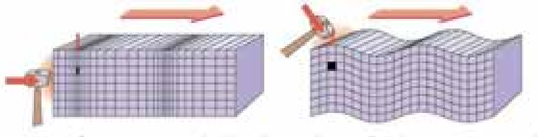


Figure 1. Left: A P Wave travels through a medium and Right: An S wave travels through a medium.

Their speed is approximately 1.7 times higher than the speed of the S-waves which always follow and have greater amplitudes. Typical speed values for P and S waves are 5.5 km/s and 3.0 km/s for granite and near Earth's surface and 1.5 km/s and 0 km/s for water. Time delay of the S-waves depends on the distance between the seismograph and the focus of the S waves. The amplitude of the P wave can move through solid rock and fluids, like water or the liquid layers of the earth. It pushes and pulls the rock it moves through just like sound waves push and pull the air. The S waves cannot travel through any liquid medium. It is this property of S waves that led seismologists to conclude that the Earth's **outer core** is a liquid.

2. Surface waves

When P and S waves meet surface layers or a discontinuity in the inner layers other type of waves are created. The prevailing ones are the surface waves. Travelling only through the crust, surface waves have a lower frequency than body waves and are easily distinguished on a seismogram as a result. Though they arrive after body waves, surface waves are almost entirely responsible for the damage and destruction associated with earthquakes. This damage and the strength of the surface waves are reduced in deeper earthquakes.

The two main types of surface waves are:
- ƒ The Love waves (LQ)
- ƒ The Rayleigh waves (LR)

Surface waves have larger amplitudes and periods and thus their role is very important especially in the behavior of large man-made structures. Their amplitudes reach their maximum near the Earth's surface and decrease exponentially with depth. This means that earthquakes occurring near the surface generate large surface waves. As the focus depth increases the amplitude of the surface waves in seismogram decreases. In earthquakes near the surface, surface waves dominate in the seismogram while for focus depths > 100 km are negligible. Therefore, we know at a quick look at a seismogram whether we have a near-surface earthquake or a deep-focus one.

The propagation velocity of LQ and LR waves depends on their frequency. The larger the frequency the lower the speed is. This means that waves with a larger wavelength will be recorded first. The LQ waves have relatively higher velocities than those of LR waves and thus are recorded first.

LQ waves move the ground from side-to-side. Confined to the surface of the crust, LQ waves produce entirely horizontal motion. LR waves roll along the ground just like a wave rolls across a lake or an ocean. Thus, it moves the ground up and down and side-to-side in the same direction that the wave is moving. **Most of the shaking felt from an earthquake is due to the Rayleigh wave,** which can be much larger than the other waves (Figure 2).

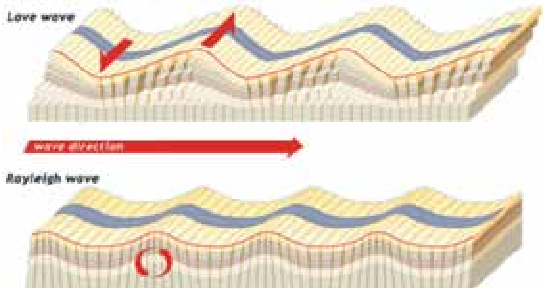


Figure 2. Top: Ground movement due to LQ waves and Bottom: Ground movement due to LR waves.

Seismic parameters

The basic seismic parameters are a) the origin time, b) the focal depth, c) the epicenter, d) the magnitude. Initial information on some of the seismic parameters is presented below.

a) **The time of origin** of the earthquake.
b) **The focus** of the earthquake (or hypocenter) which is the point where the rocks start to fracture. It is the origin of the earthquake.
c) **The epicenter**, which is the point on land directly above the focus.

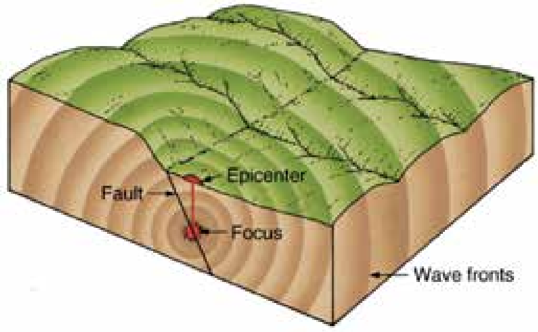


Figure 3. Focus and epicenter. Fault as well as wave fronts are also shown.

d) **The focal depth**, which is the depth at which the origin of the earthquake is located.
e) **Fault or fault plane** is the surface where two blocks of the earth suddenly slip past one another.
f) The **magnitude** of the earthquake usually measured by the **Richter scale** developed by Charles F. Richter in 1934. This is a scale

is based on a formula using the amplitude of the largest wave recorded on a specific type of seismometer and the distance between the earthquake and the seismometer. The scale is logarithmic which means that for each whole number you go up on the magnitude scale, the amplitude of the ground motion recorded by a seismograph goes up ten times. Using this scale, an earthquake of magnitude 5 would result in ten times the level of ground shaking as an earthquake of magnitude 4 (and 32 times as much energy would be released). Fortunately, most of the earthquakes that occur each year are of magnitude 2.5 or less, too small to be felt by most people.

Within the framework of this project students will focus on the origin time, the focus, the focal depth, the epicenter and the magnitude of the earthquake.

STEP 2

At this stage, students should get familiar with the use of the seismograph and be able to read a seismogram. Important information on seismograms is given below and teachers can get more information from the references at the end of the guide.

Earthquake recording on seismographs
Seismographs are instruments used to detect and record earthquakes. Generally, they consist of a mass attached to a fixed base. A seismograph is securely mounted onto the surface of the Earth so that when the Earth shakes, the entire unit shakes with it, except for the mass on the spring which has inertia, and remains in the same place. As the seismograph shakes under the mass, the recording device on the mass records the relative motion between itself and the rest of the instrument, thus recording the ground motion. In reality, these mechanisms are no longer manual, but instead work by measuring electronic changes produced by the motion of the ground with respect to the mass. The motion of the base with respect to the mass is commonly transformed into an electrical voltage. The electrical voltage is recorded on paper, magnetic tape, or another recording medium. This record is proportional to the motion of the seismometer mass relative to the Earth, but it can be mathematically converted to a record of the absolute motion of the ground. **Seismograph** generally refers to the seismometer and its recording device as a single unit. A **seismometer** is the internal part of the seismograph, which may be a pendulum or a mass mounted on a spring; however, it is often used synonymously with "seismograph".

Seismometers are oriented in one direction so that they record the ground movement (East-West, North-South or vertical). So in order to represent the ground movement due to seismic waves that reach the Earth's surface in many laboratories scientists use data from three seismometers oriented in three directions.

Seismographs are installed in the ground throughout the world and operate as **seismographic network**.

A typical seismogram
When studying a seismogram we can draw conclusions on the distance between the focus and the station as well as on the magnitude. We cannot tell with absolute accuracy where the epicenter is. For this to be done data from at least two other stations is needed. Before we will refer to this we present a typical seismogram (Figure 4).

Reading a seismogram
When you look at a seismogram, there will be wiggly lines all across it. These are all the seismic waves that the seismograph has recorded. Most of these waves were so small

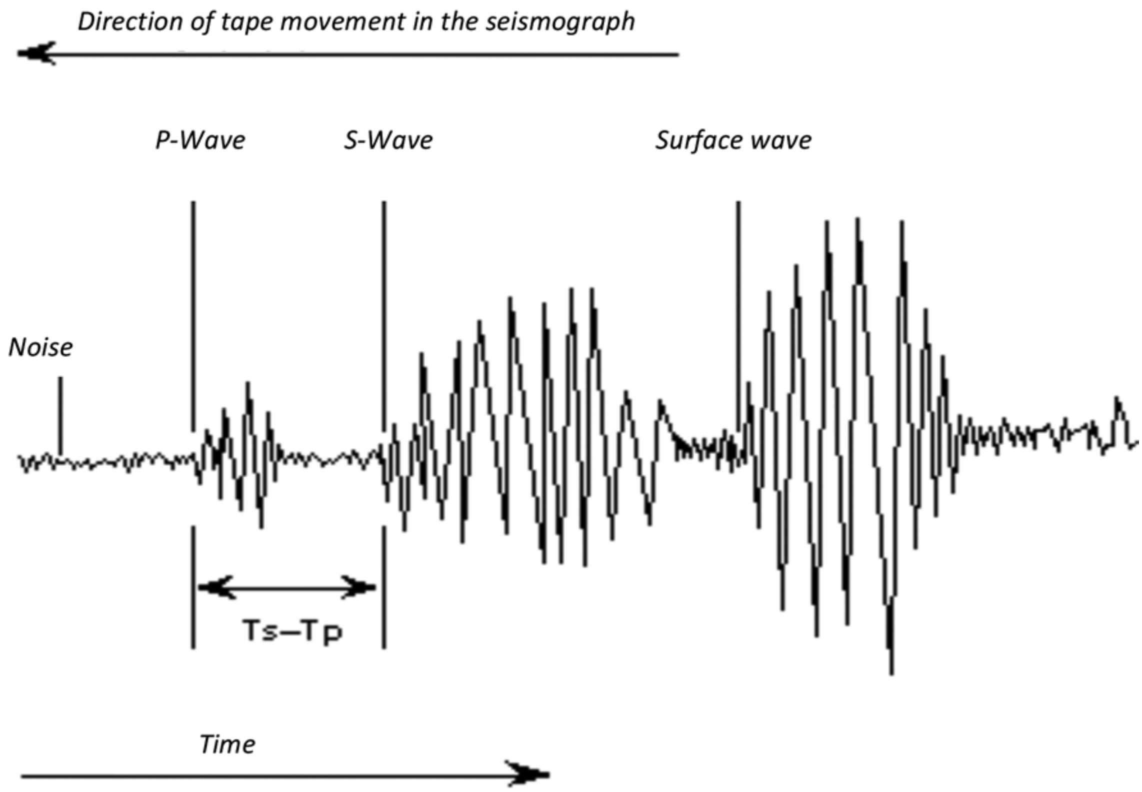


Figure 4. A typical seismogram with P, S and surface waves monitored.

that nobody felt them. These tiny **micro-seisms** can be caused by heavy traffic near the seismograph, waves hitting a beach, the wind, and any number of other ordinary things that cause some shaking of the seismograph. There may also be some little dots or marks evenly spaced along the paper. These are marks for every minute that the drum of the seismograph has been turning. How far apart these minute marks are will depend on the kind of seismograph.

The P wave will be the first wiggle that is bigger than the rest of the little ones (the micro-seisms). Because P waves are the fastest seismic waves, they will usually be the first ones that your seismograph records. The next set of seismic waves on your seismogram will be the S waves. The S waves travel at about 0.6 times the velocity of P waves. These have generally higher amplitudes than the P waves. They travel with a shearing motion which slows them, but can cause greater ground motion.
If there aren't any S waves marked on your seismogram, it probably means the earthquake happened on the other side of the planet. S waves can't travel through the liquid layers of the earth so these waves never made it to your seismograph.

The surface waves (Love and Rayleigh waves) are often the largest and longest wave sets on the seismogram. Surface waves travel slower than S waves. They travel across the surface of the globe. For really close earthquakes, the body and surface waves may appear on the seismogram simultaneously. Regional stations equidistance from a distant earthquake could have markedly different amplitudes if they are located on different substrates, though the P-, S-, and surface-wave arrival times will be about the same.

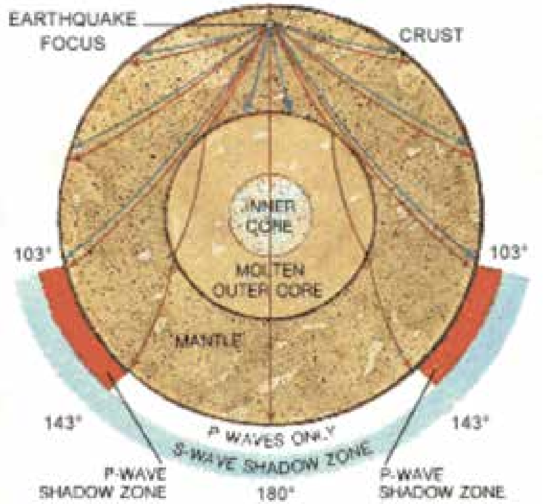


Figure 5. S waves are emitted from the focus but they cannot travel through the liquid outer core and therefore do not arrive to the other side of the planet. The zone that this happens is called shadow zone.

STEP 3

At this stage students must find the focal distance, the epicenter, the focal depth (seismic parameters) and the magnitude of the earthquake based on the seismogram.

Finding the distance between the epicenter and the station

The distance between the beginning of the first P wave and the first S wave tells us how many seconds the waves are apart. This number will be used to find how far the seismograph is from the epicenter of the earthquake. This time interval should be placed at the right part of the first scale of Figure 6. On the left part of this scale we read the distance between the epicenter and the seismic station. In the seismogram of Figure 6 S and P waves are 24 seconds away. 24 is put on the right part and on the left part we read 215 km. Thus, the epicenter is 215 km away from the seismic station.

Finding the epicenter of the earthquake

So that you find the epicenter (approximately) of the earthquake you must draw a circle with a radius equal to the number you came up above (that is 215 km). The center of the circle will be the location of the seismograph. The epicenter of the earthquake is somewhere on the edge of that circle.

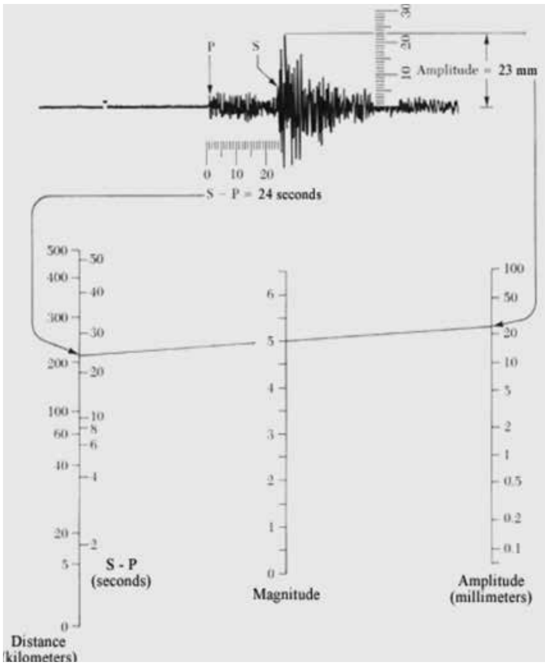


Figure 6. Finding epicenter distance and magnitude of the earthquake (BOLT, 1988)

You must follow the same procedure for the distance to the epicenter that the other seismograms recorded (with the location of those seismographs at the center of their circles). All of those circles should overlap. The point where all of the circles overlap is where the approximate epicenter of the earthquake is located (Figure 7).

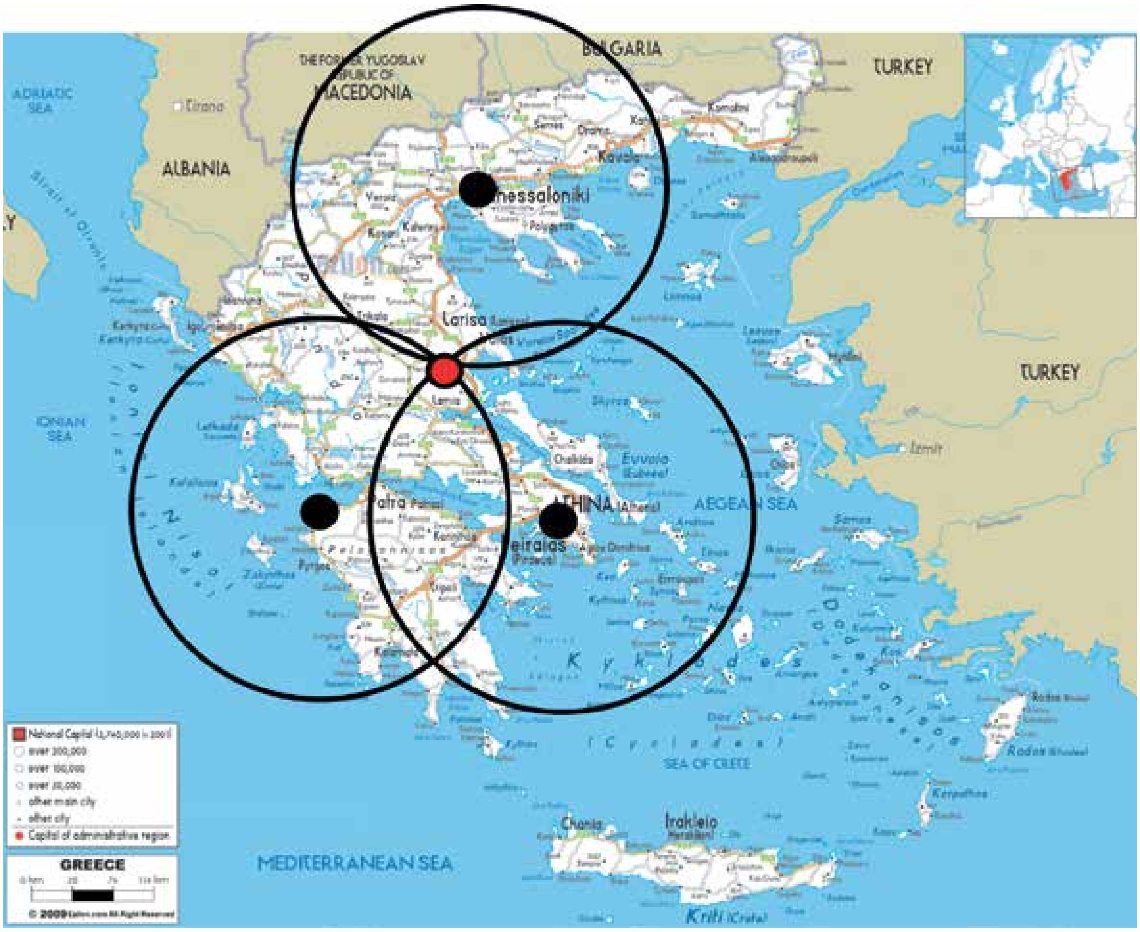


Figure 7. Finding the epicenter of the earthquake using the "triangulation" method. The point where the three circles intersect is the approximate epicenter of the earthquake.

Finding the magnitude of the earthquake
You should measure the highest wave amplitude on your seismogram. On the seismogram of Figure 6 the amplitude is 23 millimeters. Then, find 23 millimeters on the right side of the chart and mark that point.

Place a ruler (or straight edge) on the chart between the points you marked for the distance to the epicenter and the amplitude. The point where your ruler crosses the middle line on the chart marks the **magnitude** of the earthquake, showing how strong the earthquake was. In Figure 6 the earthquake had a magnitude of 5.0.

STEP 4

At this stage students should be prompted to visit http://www.gein.noa.gr/el/teleutaia-anakoinothenta and check the accuracy of their calculation on the epicenter distance and the magnitude of the earthquake. In case of deviations they should mention the possible reasons behind experimental errors. Finally, students should participate in a teleconference meeting bringing up their results on their calculations, the conclusions drawn and the experience gained.

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