

Prepared for teachers

SEISMO-Lab Demonstrators



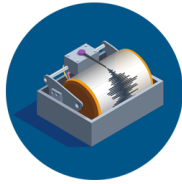
SEISMO-LAB

Project:

SEISMO-Lab Framework for
Establishing STEAM School
Competence Labs







Partners:





SEISMO-LAB

SEISMO-Lab Consortium

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Project Result 2

SEISMO-Lab Demonstrators

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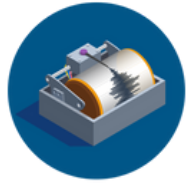
Document Control Page

WP/Task	Activity A.2
Title	SEISMO-Lab Demonstrators
Due Date	31 December 2023
Submission date	31 December 2023
Abstract	<p>The document is part of A.2 Development of Content and Educational Material. It comprises a set of educational scenarios (SEISMO-Lab Demonstrators) developed and compiled based on and meeting the criteria set in SEISMO-Lab Conceptual Framework to provide exemplary cases to teachers.</p> <p>The SEISMO-Lab Demonstrators are an essential part and tool to help schools establish open (seismology) labs for the development of student's skills and competencies as they excel in students' work and engagement in their innovative ideas to create new (student-centered) projects that could provide new best practices and educational scenarios for the whole school and its students. They are instruments for bridging the gap between formal and informal learning settings and creating new opportunities for adapting at different levels (student, teacher, school). In the end, the aim is to create a pool of demonstrators based on whole-school STEAM projects and initiatives involving external stakeholders, e.g., science centers and museums or research centers that promote creative problem solving, discovery, learning by doing, experiential learning, critical thinking, and creativity, simulating the actual scientific work.</p> <p>Earth sciences and seismology, and more specifically, the subject of earthquakes, are a perfect starting point for countless opportunities for cross-curricular activities. Based on the framework of PR1, existing identified initiatives will be enriched and expanded, taking account of (and utilizing) every student's extended learning relationships (peer-peer, student-teacher, involving parents or external mentors or businesses), so that learning is something that can happen at any time, in any place, and with a broader range of coaches, science communicators, mentors, and experts.</p> <p>The demonstrators will inspire further activities built by the different school labs. In addition, it will entail training and workshop material for the MEs and summer schools. All material will be made available in all languages.</p>

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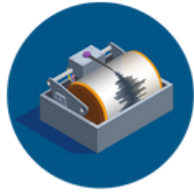


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SEISMO-LAB

Creating school seismology labs for the development of students' competences



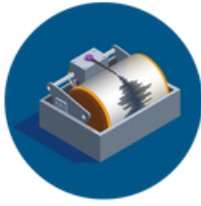
Introduction

The SEISMO-Lab Demonstrators are an essential part and tool to help schools establish open (seismology) labs for the development of student's skills and competencies as they excel in students' work and engagement in their innovative ideas to create new (student-centered) projects that could provide new best practices and educational scenarios for the whole school and its students. They are instruments for bridging the gap between formal and informal learning settings and creating new opportunities for adapting at different levels (student, teacher, school). In the end, the aim is to create a pool of demonstrators based on whole-school STEAM projects and initiatives involving external stakeholders, e.g., science centers and museums or research centers that promote creative problem solving, discovery, learning by doing, experiential learning, critical thinking, and creativity, simulating the actual scientific work.

Earth sciences and seismology, and more specifically, the subject of earthquakes, are a perfect starting point for countless opportunities for cross-curricular activities. Based on the framework of PR1, existing identified initiatives will be enriched and expanded, taking account of (and utilizing) every student's extended learning relationships (peer-peer, student-teacher, involving parents or external mentors or businesses), so that learning is something that can happen at any time, in any place, and with a broader range of coaches, science communicators, mentors, and experts.

The main activities related to the development of the Demonstrators are the following:

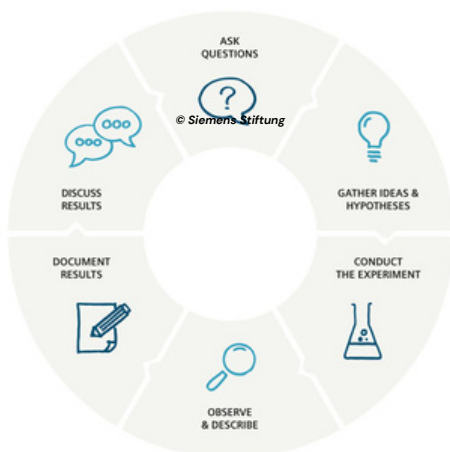
- Collecting and reviewing state-of-the-art resources and materials in school seismology, introducing RRI in schools and seismology educational projects, competence-based learning, etc.
- Analysis of scenarios along the criteria defined in the SEISMOLab Framework and proposals for the enrichment and enhancement
- Analysis of the school curricula in participating countries and identification of entry points for education activities, the definition of the main themes, content, structure, and activities of school SEISMO-Labs
- Development of new SEISMO-Lab Demonstrators



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The SEISMO-Lab Educational Scenarios Templates in the context of Demonstrators

This document section is just a concise graphical synthesis, from a literature review perspective, of the Educational Scenarios primarily presented on the SEISMO-Lab Framework, describing mainly what is expected to happen in a STEAM classroom and the most effective instructional methods to establish a culture of inquiry and deeper learning in the school classroom.



Inquiry Based Teaching

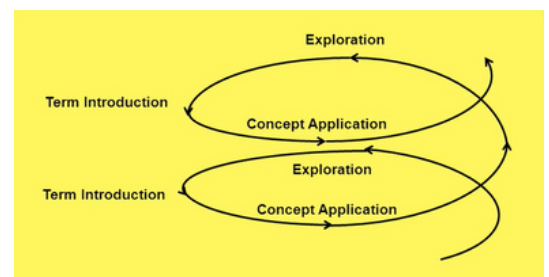
An iterative process of (1) question eliciting activities, (2) active investigation by students, (3) creation, these are (4) discussed already at early stages of the process, leading to (5) reflection about knowledge and the learning process, which in turn leads to new and refined questions (1), and the process goes on for another cycle.

IBT does not only tap into creativity, problem-solving, and critical and analytical thinking. It also sets the stage for learning how to collect and interpret data (become a science- and data-literate) and how to do this ethically and reliably. All these are skills of the 21st century, where data are abundantly available in every part of life.

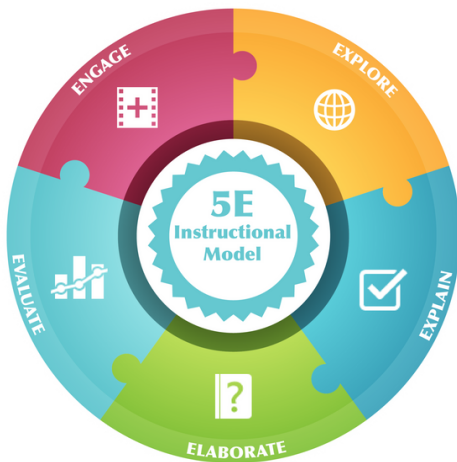
The Learning Cycle

Exploration, Concept Introduction, and Concept Application.

Lawson suggests that the use of the learning cycle provides opportunities for students to reveal prior knowledge (particularly their misconceptions) and opportunities to argue and debate their ideas. This process can result in cognitive disequilibrium and the possibility of developing higher levels of reasoning.



Lawson Learning Cycle Model (1995)



5E Instructional Model

A science teacher introduces a new concept, and students need help to reconcile the new idea with current knowledge and experience.

The teacher then provides experiences and information that help students make sense of the new conception. Then, as students consider and try to incorporate the new concept, they must see that a world in which the idea is accurate is generally reconcilable with their worldview.

Finally, students must see that there are instances where there is good reason to supply the new conception—namely, it works and helps explain things.

Project-based learning aims at giving students a highly motivating learning experience closely related to the tasks and challenges of the real world.

The projects in Project-based learning are challenging and complex tasks based on some topics, questions, or problems that drive the work in projects.

The projects at hand usually involve elements from various subjects, which makes them multidisciplinary and not bound to any particular subject domain.



Project-based Learning



Guided Research Model

Guided research teaching model of Schmidkunz & Lindemann (1992). The word research in the model description aims to help students explore the research procedures themselves. In contrast, “guided” emphasizes that this research effort will occur as a structured discovery within organized teaching.

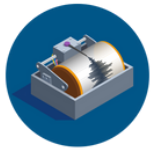
This teaching model includes five teaching stages (bringing up the phenomenon to a problem, suggesting confrontation with the situation, implementing a suggestion, abstraction of the finding, and consolidation).

Kuhlthau, C. (2010). *Guided inquiry: School libraries in the 21st century. School libraries worldwide*, 1-12.

Karplus R., et al (1980). *Teaching for the development of reasoning. In Association for the Education of Teachers of Science Yearbook*, A.E. Lawson (Ed.), *The Psychology of Teaching for Thinking and Creativity*. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Lawson A., (1988). *A better way to teach biology. American Biology Teacher*, 50(5):266-278

Schmidkunz, H. & Lindemann, H. (1992). *Das forschend-entwickelnde Unterrichtsverfahren. Problemlösen im naturwissenschaftlichen Unterricht*. Westarp Wissenschaften, Essen.



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Pedagogic Principles

As defined in the SEISMO-Lab Framework, the project activities aim to explore the idea of Learning Ecologies by developing educational scenarios (called **SEISMO-Lab Demonstrators** in the Framework of the project) by providing access to unique seismological data.

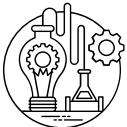
Research on learning science makes clear that it involves the development of a broad array of interests, attitudes, knowledge, and competencies. Learning “just the facts” or designing simple experiments is not sufficient. To capture the multifaceted nature of science learning, the SEISMO-Lab Framework proposes a roadmap that includes a series of “Pedagogic Principles for the design of the SEISMO-Lab Educational Activities.” It articulates the science-specific capabilities supported by the **open school environment**. This Framework builds on a four-strand model that was developed to capture what it means to learn science in school settings by adding two additional main strands incorporated for informal science learning, reflecting a particular commitment to interest, personal growth, and sustained engagement that is the hallmark of informal settings.

The main Pedagogic Principles and the Educational Objectives



Sparking Interest and Excitement

Experiencing excitement, interest, and motivation to learn about phenomena in the natural and physical world.



Understanding Scientific Content and Knowledge

Generating, understanding, remembering, and using concepts, explanations, arguments, models, and facts related to science.



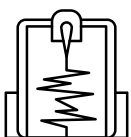
Engaging in Scientific Reasoning

Manipulating, testing, exploring, predicting, questioning, observing, analysing, and making sense of the natural and physical world.



Reflecting on Science

Reflecting on science as a way of knowing, including the processes, concepts, and institutions of science. It also involves reflection on the learner’s own process of understanding natural phenomena and the scientific explanations for them.



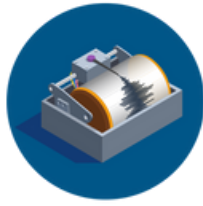
Using the Tools and Language of Science

Participation in scientific activities and learning practices with others, using scientific language and tools.



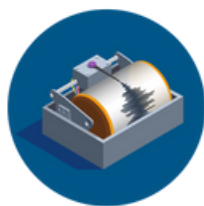
Identifying with the Scientific Enterprise

Coming to think of oneself as a science learner and developing an identity as someone who knows about, uses, and sometimes contributes to science



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[Link to national curriculum](#)



SEISMO-LAB

Link to the national curriculum of Greece



Domain:	Geography/Geology (Primary and Junior high school/Gymnasium), Physics (High school/Lyceum)	
Sub – domain:	Geology (for Primary and Junior high school/Gymnasium), Physics (Motion and Velocity, Waves)	
School level: Primary school, Junior high school/Gymnasium, High school/Lyceum	Age: 6 – 12 (Primary school), 12 – 15 (Junior high school/Gymnasium), 15 – 18 (High school/Lyceum)	Grades: 6th grade, 1st and 2nd grade,

Teaching Approach

- Investigations with 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.
- 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 may complement traditional lessons of expository instruction by teachers.

Example (earthquakes):

Position: Mediterranean area

Tools: scale maps in paper or electronic format displayed by the projector, other multimedia resources like photographs, videos

Theme: Geology and Geography

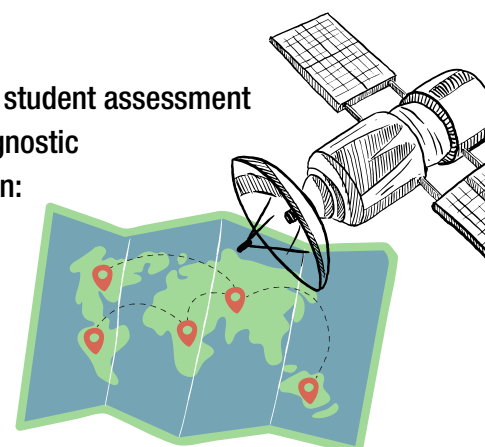
Theories: Tectonic processes

Terms: Tectonic plates, earthquakes, seismicity, volcanic activity

Evaluation

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. Examples of means of evaluation:

- questioning and observation
- creation/comparison/ understanding of thematic maps
- diagnostic tests
- interim and final exams, summative assessment



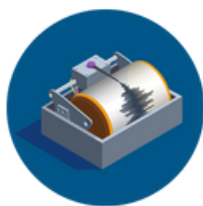


**Primary school, 6th grade
Junior high school/Gymnasium, 1st and 2nd grade**

Concept competences:	Skills competences:	Types of activities
<p>Explain that the Earth's crust consists of a number of tectonic plates. Explain what an earthquake is. Conclude from maps that the boundaries of tectonic plates are associated with seismic zones. Natural phenomena and impact.</p>	<p>Handle scale maps and globe</p> <ul style="list-style-type: none"> 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 	<p>Example of related activities:</p> <ul style="list-style-type: none"> 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
<p>Distinguish a natural hazard from a natural disaster</p> <ul style="list-style-type: none"> 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 	<p>Handle and understand scientific data</p> <ul style="list-style-type: none"> 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 	<p>Example of related activities:</p> <ul style="list-style-type: none"> 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)

**High school
1st grade**





SEISMO-LAB

Link to the national curriculum of Cyprus



Domain:	Geography	
Sub – domain:	Geology	
School level: Primary, Middle school	Age: 11 – 14 years old	Grades: 6th – 8th grade

Teaching Approach

Investigations with the use of tools (e.g., maps, photographs, charts, computer simulations) are taught to students, used, and made by students. The lessons are structured based on titles from different sections (position, tools, theme, theories, terms, and skills). Teachers must take into consideration the success indicators of the national geography curriculum. Skills are the guidelines for the organization of the activities.

Example (earthquakes):

Position: East Asia
 Tools: Small-scale maps, photographs, videos
 Theme: Geology
 Theories: Tectonic processes
 Terms: Tectonic plates, earthquakes
 Skills: Influence zone, relationships, district

Teachers must take into consideration the success indicators of the national geography curriculum.

Examples of teaching practices:

- exploratory learning
- problem-solving learning
- collaborative learning (constructivism)
- investigations
- field research

Skills (geo-literacy, epistemological adequacy) are the guidelines for choosing a teaching approach and practices that define classroom organization, tools, and teacher and student roles.

Evaluation

The success indicators of the national geography curriculum provide the evaluation context.

1. Formative assessment of the achievement of the lesson/s competencies (skills, concepts) and teaching during the learning procedure.
2. Diagnostic and final evaluation happens progressively according to specific criteria.

Examples of means of evaluation: **observation, creation/comparison/ understanding of thematic maps, portfolio, self-assessment, diagnostic tests**



6th grade

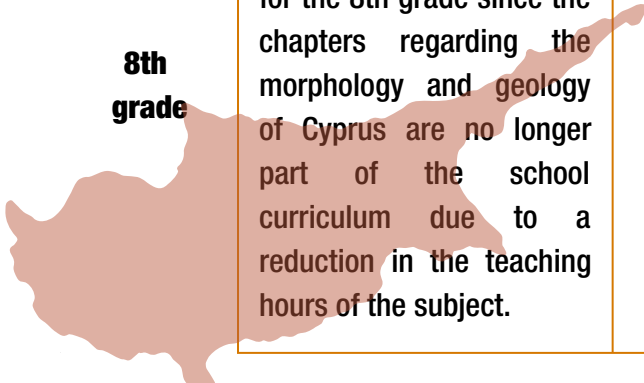
Concept competences	Skills competences	Types of activities
<p>Explain that the Earth's crust consists of several tectonic plates</p> <p>-Conclude from maps that the boundaries of tectonic plates are associated with seismic zones</p>	<p>Numerous skills are mentioned in the curriculum. Teachers choose skills, attitudes and behaviors they want to develop.</p> <p>Skill competence example:</p> <p>-Handle digital globe and maps</p>	<p>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.</p>

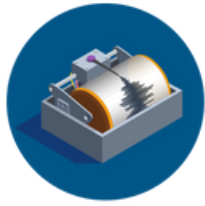
7th grade

<p>Distinguish a natural hazard from a natural disaster</p> <ul style="list-style-type: none"> • 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 disaster 		<p>A chapter referring to natural disasters and dangers (e.g. earthquakes, tsunamis, interaction between disasters), definition of basic terms describing an earthquake (magnitude, epicenter, depth, seismic waves) and information about EMAK (Special response unit for disasters)</p>
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8th grade

<p>No specific concept competences were written for the 8th grade since the chapters regarding the morphology and geology of Cyprus are no longer part of the school curriculum due to a reduction in the teaching hours of the subject.</p>		<p>Small thematic chapters that refer to:</p> <ul style="list-style-type: none"> • structure of Earth • description of tectonic plates movements • creation of Cyprus • types of stones <p>With gap filling exercises and closed questions after each chapter</p>
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SEISMO-LAB

Link to the national curriculum of Italy



Domain:	Science, physics	
Sub – domain:	Earth science	
School level: High school	Age: 14 - 18 years old	Grades: 9th - 13th grade

Teaching Approach

The study of seismology is more or less in-depth, depending on the curricular background of the teacher. It is generally less significant than chemistry, biology, and experimental laboratory 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, their students may be involved in practical experiences.

Evaluation

According to the program indications in science by the Italian Ministry of Education, students should attend periodic evaluation tests.

The main Italian school publishers provide teachers with thematic test models in curricular subjects.





Concept competences	Skills competences	Types of activities
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Age: 14 - 18

9th - 13th grade

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.).

To know what an earthquake is and contextualize these 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

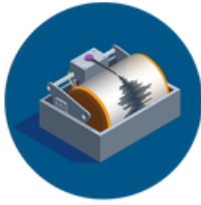
To be aware of seismic risk, with a particular focus on the risk in the territory where they live, and of a correct behavior in case of earthquakes

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.





SEISMO-LAB

Link to the national curriculum of Romania



Domain:	Science, physics	
Sub – domain:	Earth science	
School level: High school	Age: 14 - 18	Grades: 9th - 13th grade

Teaching Approach

In Romania, subjects specific to seismology, in general, and Earth Sciences, in particular, are taught integrated into the primary cycle. In the gymnasium, some notions are integrated into Geography and in high school, in particular in Physics (seismic waves), geography (Earth's internal structure and natural hazards), and civic education (notices about seismic risk and preventive behavior). Despite the above facts, many science contests and national Olympiads are frequently organized, and constant and consistent student participation and outstanding results are obtained.

Interested teachers use the training and professional development opportunities offered by initiatives such as the Romanian Educational Seismic Network and apply ideas and examples of experiments where the discipline and the subject allow it but in a sporadic and mostly informal way.

Evaluation

The evaluation will follow the formative aspect and contribute to the student's motivation and encouragement.

Systematic observation, self-assessment, posters, constructed devices, practical skills, reports, expressed interest, involvement, and contribution to group work are some sources of information about students' level of knowledge and skills.

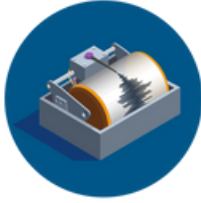
The evaluation will correlate the traditional methods with the modern ones. It will emphasize the school's progress, the use of the most varied forms of communication of the school results, their correlation with the specific skills, and the identification of the skills acquired in non-formal or informal contexts.





Age: 15-18
9th - 12th grade

Concept competences	Skills competences	Types of activities
<p>Knowledge and understanding of physical phenomena, terminology, specific concepts</p> <p>Development of exploratory capacities (investigation of reality), as well as development of the capacity for practical application of learned notions, using appropriate tools and procedures</p> <p>Developing communication skills using a scientific language</p> <p>Developing a critical attitude towards the effects of science on technological and social development, as well as the interest towards protecting the environment</p> <p>Development of data processing, analysis and interpretation capabilities using a developed mathematical support</p>	<p>Developing teamwork and collaboration skills</p> <p>Comparing some quantitative data sets and confronting the conclusions obtained by different working groups</p> <p>The correct use of terms in the description of some phenomena</p> <p>Explaining the observed phenomena based on the knowledge acquired in different school subjects; identifying possible consequences of the phenomena related to the occurrence of earthquakes on life on Earth and the environment consulting various sources of information and modern means of documentation to explain the studied phenomena</p>	<p>Identifying the ideas and knowledge that the students possessed in relation to the structure of the Earth, the production of earthquakes, the propagation of seismic waves</p> <p>Assessing the conditions for the realization of a phenomenon and formulating working hypotheses</p> <p>Identifying and discussing the mistakes students make in defining, explaining and characterizing observed phenomena</p> <p>Tracking and explaining the causes that determine the occurrence of earthquakes practicing the spirit of observation and the technique of following a studied phenomenon</p> <p>Experimental data recording</p> <p>Collecting, ordering and interpreting experimental data regarding seismic wave propagation and designing simple tools for observing phenomena.</p> <p>The use of models as a complementary way of presenting data</p> <p>The evolution of ideas and the contributions of some scientists in the development of knowledge in the field of seismology;</p>



SEISMO-LAB

Link to the national curriculum of Turkey



Domain:	Science	
Sub – domain:	Physical Events	
School level: Secondary school	Age: 13 - 14	Grades: 8th grade

Teaching Approach

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 strategies for students. In this regard, informal learning environments like science, art, archeology museums, zoos, and natural habitats are also used. The process of research and questioning is not only regarded as exploration and experiment but also as the process of explaining and creating arguments. In short, the students make the information in their minds by practicing-experiencing-thinking like scientists. Teachers allow their students to participate 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 reasons that they create through valid data. Teachers take the role of guiding directors in these written or verbal discussions that have opposite theses.

Evaluation

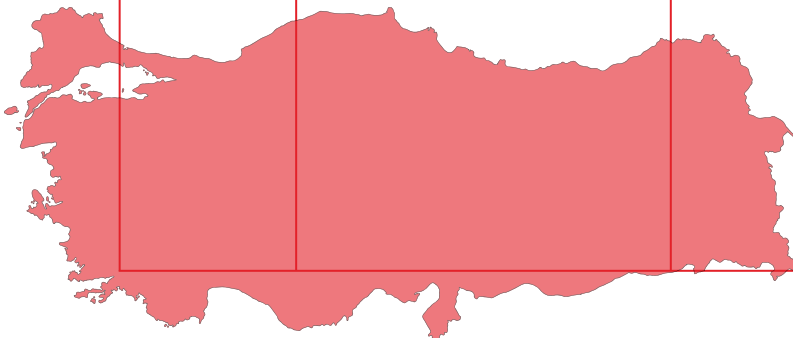
The geography curriculum has adopted an assessment approach that intends to monitor and direct students in the process, identify learning difficulties and eliminate them, and support meaningful and permanent learning by providing continuous feedback. Having a meaning of the numerical values obtained in the result, the monitoring of student progress and the direction of the student according to this progress are among the essential principles of the curriculum. The point of view based on assessment depends on the assessment's understanding of evaluating the process and the product, so it is suggested that together with the learning outcome, the student's performance should be assessed at the end of the process. It is also recommended that complementary assessment tools and techniques be used since the numerical values obtained through traditional assessment tools do not have meaning alone. Complementary assessment tools and practices and a process-oriented assessment approach are emphasized. Finally, self-assessment and peer assessment approaches by which the student has the chance to evaluate himself and his friend are adopted. Also, technology is used to monitor and assess students' learning process and their performance at the end of this process.

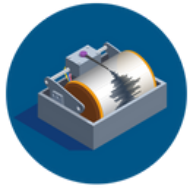


Age: 13-14

8th grade

Concept competences	Skills competences	Types of activities
<p>Define general concepts on seismology such as seismologist, aftershock, foreshock, intensity of earthquake, fault line, fault line break, earthquake zone;</p> <p>Make a connection between Turkey's earthquake zones and fault lines;</p> <p>Argue about reasons of earthquake and emergent adverse outcomes;</p> <p>State that not only fault lines but also volcanic eruptions cause earthquakes;</p> <p>Discuss precautions against the risk of earthquake, and things to be done during an earthquake.</p>	<p>Developing research and data collection skills about natural disasters.</p> <p>Developing projects on earthquakes and their risks. Develops the ability to hypothesize, question, collect data, and conduct scientific studies.</p> <p>Developing collaboration and teamwork skills</p>	<p>Reading the news on the newspapers and internet about the big earthquakes in Turkey in the classroom.</p> <p>Watching a movie of how earthquakes happen.</p> <p>Students are given an investigation to search what can be done before, during and after earthquakes and then explain these precautions in the classroom.</p>






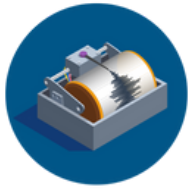


SEISMO-LAB

SEISMO-Lab Demonstrators

Title	Template scenario	Abstract	Partner
<i>How to build a seismometer</i>	PBL, IBL	<p>The activity aims to challenge young students of all ages to design and build an instrument able to record vibrations in general and ground motion in particular. Depending on their ages and the way they organize themselves (individuals, groups of students, or coordinated by an adult), the prototype can be from a simple box built using common materials to a more advanced, able even to record in digital format the Earth movement. For being able to do so, the students need to follow an inquiry-based approach to ask questions and investigate the real-world problem represented by earthquakes and especially their effects on landscape and humans.</p>	
<i>Print your shake table and build a better wall</i>	PBL	<p>This activity focuses on participatory, inclusive, and cross-curricular learning challenges that will engage students in activities that increase their problem-solving skills and stimulate their creativity. Following this tutorial, students will reinforce their skills in using a 3D printer, enhance their technical abilities by assembling the shake table, and develop critical thinking by building and testing an earthquake-resilient structure. The workgroup (age 14-18) will participate in meaningful and motivating science inquiry activities on earthquake disaster mitigation and will find and implement structural solutions to improve a building's response to the horizontal component of a seismic wave.</p>	
<i>Seismo Theater</i>	5E	<p>Students (ages 10-12) will put on a theatrical show about earthquakes, where an audition will not decide the distribution of roles, but the earthquake's characteristics will determine it (i.e., the role of the P-wave must be given to a fast student, while the role of the S-wave to a slower student). Students must study the characteristics of various parameters of an earthquake and distribute the roles among them.</p>	

Title	Template scenario	Abstract	Partner
<p><i>How to estimate the magnitude of seismic shocks by comparison</i></p>	<p>PBL, 5E</p>	<p>The local seismic magnitude is a dimensionless quantity even if its calculation is based on the numerical entity of the ground displacement at a given distance from the epicenter. Although the seismic data (i.e. waveforms) that students could acquire from both the research networks and the educational network of the SEISMO-Lab project do not directly provide the physical measurement of ground displacement, these data can be used to estimate the local magnitudes of shocks comparing them to a reference shock of known magnitude.</p> <p>This activity is aimed at high school students (16-18 years old) and aims to familiarize the participants with this peculiar concept.</p>	
<p><i>Finding the velocity of P waves using real data collected from SEISMO-Lab seismometers</i></p>	<p>PBL. 5E</p>	<p>The aim of this activity is to find the velocities of P waves using the data obtained from the seismometers installed within the framework of the seismo-lab project. This activity also enables students to gain more in-depth knowledge of earthquake-related topics and to analyze earthquake data using their IT skills. This activity requires time and distance data. The distance can be found using Google Earth (ruler) between the point of the earthquake epicenter. The time for the p waves between epicenter and the station can be found using SWARM software. It is expected from students to use these data to calculate the velocity of the P waves.</p> <p>More details can be found at: turkey- educational scenerio.pptx</p>	
<p><i>Sound of the Earth</i></p>	<p>IBL</p>	<p>Transforming scientific data into music employing hands-on exercises and digital technologies. A complex science subject but also a common phenomenon to many places on Earth, such as earthquakes, are introduced to students via a creative and inspiring approach. Students investigate online earthquake data, learn how to process them, and use sonification techniques to transform seismograms into musical pieces, thus listening to and performing “The Sound of the Earth.”</p> <p>Curriculum: Mathematics (functions), Physics (sound and its parameters), Geology (earthquakes), Music</p>	



SEISMO-LAB

How to build a seismometer



Description of the activity

The activity aims to challenge young students of all ages to design and build an instrument to record vibrations in general and ground motion in particular. Depending on their ages and the way they organize themselves (individuals, groups of students, or coordinated by an adult), the prototype can be from a simple box built using everyday materials to a more advanced, able even to record in digital format the Earth movement. For being able to do so, the students need to follow an inquiry-based approach to ask questions and investigate the real-world problem represented by earthquakes and especially their effects on landscape and humans.



Activity type:

Guided Research Model



Duration

8 hours



team work



Target group

High school students



Educational problem

Earthquakes happen all the time. Still, most of them are so small that we can't feel them, and they do not cause any damage. A **seismograph** is a device used to measure the motion of the ground during an **earthquake**. Seismographs are very sensitive and can detect earthquakes that occur very far away (along with other things that shake the ground, like volcanic eruptions or large explosions) that might be too faint for humans to feel. Seismographs are made by hanging a heavy weight from a rigid frame connected to the ground. When the ground moves during an earthquake, the frame moves back and forth along with the ground. However, the heavyweight is not connected directly to the ground, and it wants to stay in place due to inertia. The result is that the weight holds still while the frame moves back and forth around it. The relative motion of the weight and frame can be turned into a seismogram recording. The seismogram can be analyzed later to find out when an earthquake happened and how strong it was. Today seismographs record this motion as an electrical signal.

Introducing students to:

- The science of earthquake formation and detection
- Directly apply physical principles (e.g. inertia, electromagnetic induction)
- Improving of different practical skills
- Analysing data of real earthquakes and observe their characteristics



Educational approach

Students will:

- investigate the ground motion and learn how this movement can be graphically represented
- gain a greater appreciation of how a seismograph works
- gain a better understanding of the ground motion recordings they see on seismograms

This is an 8 (didactical) hours educational activity that includes:



- *an introduction to seismology*
- *the building and operation of a seismometer*
- *the characteristics of the waveform*

Learning activities - steps and suggestions

General information

Duration:

8 hours

Vocabulary:

- earthquakes, seismometer, seismogram
- seismic wave

Tools and materials:

As described in Annex 1

Purpose and objectives:

Students will gain a greater appreciation of how a seismograph works and a better understanding of ground motion recordings they see on seismograms.

Student's Misconception: often, students consider that the earthquakes that are felt are the only ones that occur, and thus their number and frequency are much lower than in reality

Before you begin the activity

1. Presentation of the concept/problem/theory:

Earthquakes happen all the time, but most of them are so small that we can't feel them, and they do not cause any damage.

A seismograph is a machine used to measure the motion of the ground during an earthquake. Seismographs operate on the principle of inertia of stationary objects.

Seismograms are the graphs of the motion of the ground versus time. They are the squiggles left by the pen or produced by digital computer records. Seismograms are used to calculate the location and magnitude of an earthquake.

2. Suggestions:

- Basic tinkering skills such as: assembling parts of the shake table, drilling holes are required.
- It is recommended that the students should be assisted by a ICT teacher or someone with similar knowledge.



Discussion:

Students can organize debate groups and present their solutions to the teachers.

Educational phase

Help students understand how seismographs work by building their simple seismographs.

- Stimulation - creative thinking in finding constructive solutions for earthquake resilience.
- Experimental activities - building a seismograph and understanding its working principles.
- Observation - discussion - scientists study earthquakes so we can understand them better and hopefully one day predict them so we can save thousands of lives.
- Consolidation - students will apply physical concepts and will understand how seismographs work.
- Exercises - students are encouraged to design and test their seismographs.



Consolidation

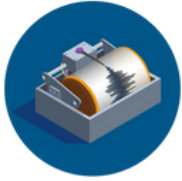
Throughout this activity, students will work in teams and will enhance their constructive skills and critical thinking.

They will apply the knowledge and physical principles and understand how a seismograph works.

Go to Annex 1



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SEISMO-LAB

Print your own shake table and Build a better wall



Description of the activity

This activity focuses on participatory, inclusive, and cross-curricular learning challenges that will engage students in activities that increase their problem-solving skills and stimulate their creativity. Following this tutorial, students will reinforce their skills in using a 3D printer, enhance their technical abilities by assembling the shake table, and develop critical thinking by building and testing an earthquake-resilient structure. In addition, the workgroup (age 14-18) will participate in meaningful and motivating science inquiry activities on earthquake disaster mitigation and will find and implement structural solutions to improve a building's response to the horizontal component of a seismic wave.



Activity type:

PBL - project based learning



team work



Duration

2 modules of 3 hours each (6 hours)



Target group

High school students



Educational problem

Helping students understand how earthquakes affect our society and address steps they can take to mitigate earthquake risk while learning basic earthquake engineering principles. Students explore how diagonal braces, shear walls, and rigid connections strengthen structures to carry forces resulting from earthquake shaking. Also, students improve their technical skills and critical thinking by printing and assembling a shake table.

Introducing students to:

- Using a 3D printer to print out the needed components
- Constructive skills needed for assembling the shake table and the test structure
- Recognize the structural elements of a building
- Describing basic engineering notions of how to improve a structure as the horizontal and vertical structural elements carry the horizontal and vertical loads of a building
- Observe and analyze the test output before and after the structural enhancement.



Educational approach

Students will:

- learn about the structural elements of a building
- understand how horizontal and vertical structural elements carry the horizontal and vertical loads of a building.
- understand how diagonal braces, shear walls, and rigid connections provide paths for the horizontal load resulting from an earthquake.
- be encouraged to design and test shear bracing for a wall to help it withstand earthquake-like shaking.

This activity can be introduced with the previously printed components in two modules of 3 hours each (6 hours in total). The first module will presume to assemble the shake table and understand the operating principle. The second module will consist of confectioning a structure, testing it, and enhancing it to withstand the horizontal component of an earthquake.



Learning activities - steps and suggestions

General information

Duration:

Two modules of 3 hours each (6 hours in total)

Vocabulary:

- basic notions of seismology,
- seismic resilience,
- earthquake engineering

Instruments and materials:

As described in Annex 2

Purpose and objectives:

Students will understand the basic principles of earthquake engineering

Student's Misconception: students often consider a taller building more vulnerable than a smaller one. We aim to demonstrate that applying the proper solutions can enhance a structure's resistance to an earthquake.

Before you start the activity

1.Presentation of the concept/ problem/ theory:

Earthquakes can seriously affect buildings and structures. During an earthquake, structures are more vulnerable at the horizontal component of movement. In order to enhance a structure's response students will apply different constructive solutions and observe the results.

2. Sugestions:

- It is recommended that the workgroup should be familiar with a 3D printer. Basic tinkering skills such as: assembling parts of the shake table, drilling holes into the wooden blades
- it is recommended that the students should be assisted by a ITC teacher.

Educational Phase



Discussion:

Students can organize debate groups and present their solutions to the teachers. Moreover, they can set an experimental stand in the school to explain the phenomenon to their colleagues who still need to gain the skills of assembling a shake table and building a structure.

- Stimulation: creative thinking in finding constructive solutions for earthquake resilience
- Experimental activities: building a shake table and understanding its working principles. Building a vulnerable structure and then enhancing it to withstand an earthquake
- Observation - discussion: students will identify how diagonal braces, shear walls, and rigid connections provide paths for the horizontal load resulting from an earthquake.
- Consolidation: students will gain an overall understanding of how earthquakes affect buildings and how they can be enhanced
- Exercises: students are encouraged to design and test shear bracing for a wall to help it withstand earthquake-like shaking.



Consolidation

Throughout this activity, students will work in teams and will enhance their constructive skills and critical thinking.

In the first stage, they will understand the need for experimental testing and how a shake table can provide the start base for testing a building's response to an earthquake.

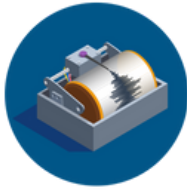
In the second stage of the activity, students will build and test a structure and observe its behavior during an earthquake. Following this experience, they will try to find solutions to enhance the structure's response to an earthquake.

This activity will bring students to focus on a new insight into seismic resilience and help them acknowledge the importance of seismic safety measures and codes.

Go to Annex 2



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SEISMO-LAB

The Seismo -Theatre



Description of the activity

Taking advantage of real-life problems and phenomena can capture students' innate curiosity about natural wonders in the world around them. This curiosity can be used to teach a wealth of critical cross-curricular competencies, skills, and fundamental principles.

Driving problem: What are the essential roles of putting on a theatrical show about earthquakes, and how can we distribute these roles among the students?



Activity type:
5E



team work



Duration -



Target group
Students - 10-12 years old



Educational problem

Traditional education rarely engages students in real-life phenomena causing them to struggle to find the relevance of what they are studying in school. Especially in Sciences, students often feel overwhelmed by the required knowledge and skills load without feeling motivated to engage with the subjects. Furthermore, relevant information and knowledge are fragmented into different, often seemingly unrelated disciplines.

Specific drawbacks:

1. Students limited mathematical skills
2. Lack of students engagement
3. Textbook-based instruction
4. Limited collaboration between teachers from different disciplines

Characteristics and needs of learners

- Cognitive: students have less than average knowledge levels of mathematics and geometry, and limited knowledge of science subjects.
- Psychosocial: Based on statistics, less than 50% of the students have a significant interest in science.
- Students struggle to find connections between different disciplines, what they learn in school, and their real-life experiences.
- Needs: Learners need more participatory schemes of instruction. Learners must be involved in the process and act as team members.



Educational approach

Objectives:

1. Students should be able to relate the generation of an earthquake to the relative movement between tectonic plates.
2. Students should be able to relate an earthquake with the production of two waves.
3. Students must discriminate the primary and secondary waves based on speed.

Learning activities - steps and suggestions

Step 1. Engagement

Duration: 45 minutes

Teachers involved: Science & Arts teacher

Instructions:

The school Science and Arts teachers inform students that at the end of the semester, they will put on a theatrical show about earthquakes and need to study seismology to identify and distribute the roles between them. In addition, the science teacher presents some recent seismic events to capture students' attention. For example, the science teacher presents the earthquake as a three-phase phenomenon (**Generation, Propagation, Detection**).

Step 2. Exploration

Duration: 240 minutes (3 x 80minutes)

Teachers involved: Science teacher

Instructions:

Students must explore the various phases of an earthquake, from its **Generation** (tectonic plates) to its **Propagation** (Primary, Secondary, and Surface waves) and its **Detection** (seismograph). Teachers can use previously developed lesson plans for each of the three phases.

Phases

1. Earthquake generation (80 minutes) - What is the relation between tectonic plates and earthquakes?

https://portal.opendiscoveryspace.eu/sites/default/files/what_is_the_relation_between_tectonic_plates_and_earthquakes.pdf



Goal:

Students should be able to relate the generation of an earthquake to the relative movement between tectonic plates.

2. Wave propagation (80 minutes)

Students must identify two types of waves based on their speed and the way they oscillate.

Teachers can use the previously developed lesson plans “Seismic Waves” and “Seismic Waves propagation” (currently available only in Greek, *will be translated soon). The teacher can use the following video:

https://www.youtube.com/watch?v=BxtiKodKq_E&ab_channel=CambridgeVolcanoSeismology



Goals:

1. Students should be able to relate an earthquake with the production of two waves.
2. Students must discriminate the primary and secondary waves based on their speed and way of oscillation.

3. earthquake detection (80 minutes):

Students are given seismographs depicting earthquakes and are asked to observe the waveforms, identify the different types of waveforms, and try to relate them to the seismic waves. The teacher can use the following simulation:

<http://ds.iris.edu/seismon/swaves/index.php>



Goals:

1. Students must relate the generated seismic waves with the corresponding waveforms in a seismograph.
2. Students should be able to relate the time distance between the P-S waves with the distance between the earthquake's epicenter and the seismograph.

Step 3. Explanation

Duration: 160 minutes

Teachers involved: Science & Arts teacher

Instructions:

Students must identify the roles for each phase based on their previous exploration, identify their characteristics, and devise a plot for the show.



Roles

- **Earthquake Generation:** The core idea of this phase is that there must be a relative movement between at least two tectonic plates for an earthquake to be generated.
- **Tectonic plates colliding** (2 roles)
- **Wave Propagation:** The core idea of this phase is that the relative movement of two tectonic plates produces two types of waves with different speeds and ways of oscillation.
- **P-wave** (1 role for each direction), **S-wave** (1 role for each direction)
- **Detection:** The core idea is that to identify an earthquake, we need a seismometer, and to find the earthquake's origin, we need more Seismometers (1 role for each seismometer).
- **Additional roles:** Seismologist role, expert safety role.



PLOT



At least two students (tectonic plates roles) chose the earthquake's origin location and stayed there pushing each other.

When they start colliding, pairs of students (1 fast student for the P- wave and one slower student for the S-wave role) start running in a straight line in different directions. Then, in various spots away from the epicenter, students, with their eyes and ears covered, try to identify the earthquake and its location (seismometer roles).

When the p-wave students reach the seismometers-students, they alert them by shaking their hand the way the p-waves oscillate, and the seismogram students start counting in seconds.

When the s-wave students reach the seismometers-students, they start shaking their other hand the way the s-waves oscillate, and the seismogram students stop counting and start shouting, "earthquake X seconds away."

When all the seismograms-students are triggered, the seismologist draws circles around them, based on their measurements multiplied by a constant number, and locates the epicenter.

Step 4. Elaboration

Duration: 80 minutes
teacher

Teachers involved: Science & Arts

Instructions:

Students must inform their Art teacher about the show's plot and the crucial roles they have identified and distribute them based on their characteristics between them. Then the student must rehearse their roles and the story before putting on the show.

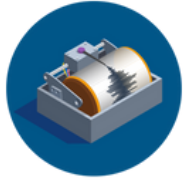
Step 5. Evaluation

Duration: 45 minutes

Teachers involved: Science teacher

Instructions:

Students put on the theatrical show for the whole school.



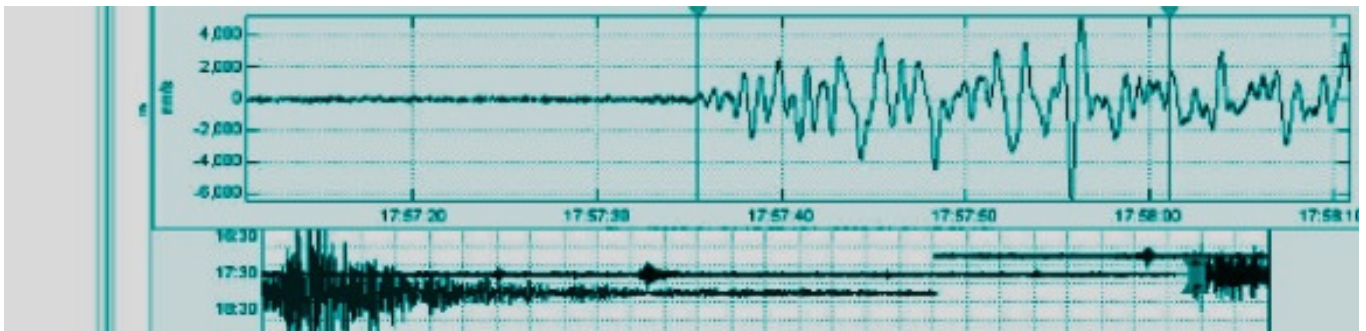
SEISMO-LAB

Finding the velocity of P waves using real data collected from SEISMO-Lab seismometers



Description of the activity

This activity aims to find the velocity of P waves using the data obtained from the seismometers installed within the framework of the seismo-lab project. This activity also enables students to gain in-depth knowledge of earthquake-related topics and analyze earthquake data using their IT skills.



Activity type:
PBL -5E



team work



Duration



Target group
Students - 10-12 years old



Educational problem

One of the essential concepts in learning earthquake subjects is wave movements and the speed of these waves. The educational problem in this activity is finding the velocity of the P wave.

To find the velocity of the P Wave, displacement and time data from the formula $x=v.t$ are needed.

These data are readily available from SEISMO-Lab stations.

Students will be introduced to:

This activity requires time and distance data. The distance can be found using Google Earth (ruler) between the point of the earthquake epicenter.

The time for the p waves between the epicenter and the station can be found using SWARM software.

Students are expected to use these data to calculate the velocity of the P waves.



Educational approach



Students are expected to have prior knowledge of earthquake-related issues. Especially in the Explore and Explain phase of the 5E learning cycle, the teachers should provide the knowledge and skills needed by the students.

In addition to these situations, teachers and students should know the use of google earth, the seismo-lab data platform, and Swarm programs.

Learning activities - steps and suggestions

General information

Duration:

Vocabulary:

- Epicenter
- P waves
- Velocity
- Time
- Displacement
- Data processing
- Data analysis
- Earthquake
- Waveform

Instruments and materials:

Internet-connected PC, SEISMO-Lab Platform, Google earth - details in Appendix 3

Purpose and objectives:

Find the velocity of P waves using real data collected from SEISMO-Lab seismometers.

Student's Misconception:

Many students confuse the concepts of magnitude and intensity. For this reason, preventing students from entering the learning environment with these misconceptions is necessary. For this reason, correcting students' existing misconceptions in the engage and explain part of the 5E learning cycle is recommended.

Before you start the activity

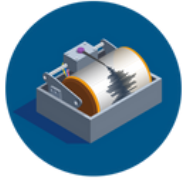
1. Presentation of the concept/ problem/ theory:

In this activity, the velocities of P waves will be placed in a table using earthquake data obtained from SEISMO-Lab earthquake stations.

By comparing the velocities of the P waves in this table, it will be tried to reveal how fast the P waves move on average.

Go to Annex 3

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SEISMO-LAB

How to estimate the magnitude of seismic shocks by comparison



Description of the activity

Often in our daily life, we hear and talk about the magnitude of an earthquake that has occurred somewhere without knowing exactly what it is. To make high school students aware of this peculiar scientific concept, it would be useful to better understand its mathematical meaning through practical experiences by calculating the magnitude of real earthquakes using real seismic data, such as those provided by the SEISMO-Lab network.

This demonstrator proposes a procedure to allow a teacher to carry out this type of experience with his students, bypassing the problem due to insufficient information in a raw waveform.



Activity type:
IBT / 5E



Duration:
8 hours



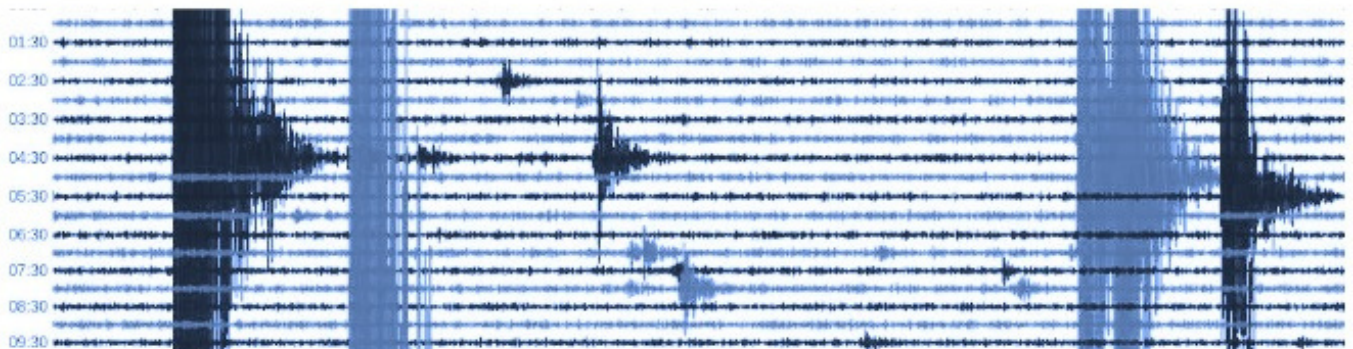
team work



Target group
High school pupils (16-18 years old, 11th-13th degree)

Students will be introduced to the following:

- How to read a Cartesian graph
- Concepts of powers of ten and decimal logarithm





Educational approach

Guided by their teacher, the students familiarize themselves with the interpretation of seismic waveforms by learning to analyze them as mathematical functions, thus referring to the mathematics curricula of the final grades of high school.

The hands-on experience of working with real data makes the educational experience more effective than a regular theoretical lesson.



For this activity, students need to be familiar to:

- *Arithmetic proportions*
- *Powers of ten and decimal logarithms*

Learning activities - steps and suggestions

General information

Duration:

Two activities lasting two hours each

Vocabulary:

- Seismograph, waveform
- Ground displacement
- Motion
- Velocity and acceleration
- Power of ten
- Decimal logarithm

Instruments and materials:

Computer classroom, internet connection, Seisgram2K software - see Appendix 4

Aims and objectives:

Deepen the concept of seismic magnitude through practical experiences.

Student's Misconception:

Students often think of magnitude as expressed by a linear scale.

Before you start the activity

1. Presentation of the concept/ problem/ theory:

This is a 4 (didactical) hours educational activity that includes:

- introduction
- Example 1, the seismic sequence of November 23rd, 2022, in Golyaka-Duzce, Turkey
- Example 2, the seismic sequence of November 29th, 2022, in Euboea, Greece
- Appendix A, Procedure for the acquisition of waveforms from the SEISMO-Lab seismic network

Teacher support:

The teacher will provide the students with preliminary material and is advised to discuss it with them before the beginning of the activity.

Educational phase

1. Stimulation:

- Theoretical introduction to the concept of magnitude and meaning and interpretation of waveforms.

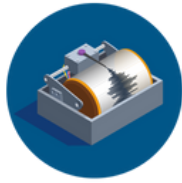
2. Experimental activities:

- Identification of seismic events helpful in carrying out the experience; acquisition of related waveforms; determination of magnitude values by comparing different waveforms.

Go to Annex 4



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SEISMO-LAB

The Sound of the Earth



Description of the activity

The standard way to depict earthquakes and explain their characteristics has been using “snapshots” of the waveforms measured by seismic stations across the earth. By studying and combining the information obtained by these static images, scientists can understand the properties of earthquakes and discover the properties of their sources and their generation mechanism. However, using these visual displays alone presents the problem of adequately explaining even the most fundamental characteristics of seismic waves, such as the waveforms of Primary (P) and Secondary (S) waves as well as more complex properties of seismic waves, such as their frequency content, their attenuation, and others. This is particularly important in science education, in which students do not have prior knowledge concerning earthquakes. To address these topics, data sonification or audification builds on people’s ability to learn through auditory stimuli and analyze complex phenomena through sound cues such as amplitude, pitch, and frequency. In this demonstrator, students will be introduced to earthquake data and will investigate earthquakes’ fundamental characteristics by converting these data into sounds



Activity type:
Guided Research Model



team work



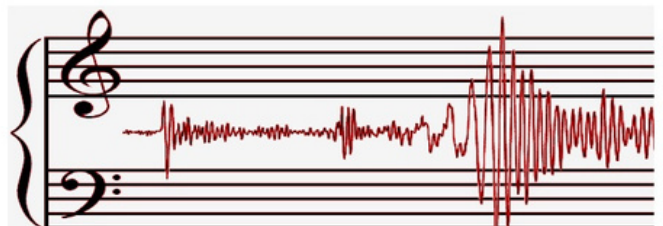
Duration:
8 hours



Target group
Students of 3rd class of Gymnasium (15 years old) and of the 1st class of Lyceum (16 years old)

Students will be introduced to the following:

- 1.The science of earthquake formation and detection.
2. Search, retrieval, use, and analysis of big data from scientific databases.
3. The method of sonification of experimental data.
4. Use sonified earthquake data to understand and measure fundamental characteristics of earthquakes and learn how to disentangle earthquakes from different sources.
5. Understand the similarities between visual representations of an earthquake and audible representations of frequencies





Educational approach

Students will investigate the earthquake magnitude scales by identifying them with sounds of natural phenomena of equal energy output, will analyze, investigate and sonify waveforms of earthquakes detected by school-based seismometers developed in the framework of the project playfully, and finally compose their music based on the sound of the Earth itself.

The domain-specific objectives of the activity are:

1. Students apply the fundamental physics of waves to understand the sonification process of earthquake data.
2. Students learn about earthquakes' generation and detection principles and their fundamental characteristics and observable quantities.
3. Students learn how to tell apart earthquakes created by different sources based on interpreting experimental data.
4. Students understand the correlation between numerical data, mathematical graphs, and audible spectrums.
5. Inquiry process of scientific concepts.
6. Recognize, analyze, and imagine alternative explanations and models.
7. Combining science with art (music).

General skills objectives:

1. Students make sense of scientific data and produce artistic representations.
2. Students enhance their analytical and synthetical skills.

Learning activities - steps and suggestions

General information

Duration:

8 hours

Vocabulary:

- Data processing
- Data analysis
- Earthquake
- Waveform
- Sonification
- Waves
- S-P waves
- Frequency
- Amplitude
- Musical scales.

Instruments and materials:

A computer laboratory with one PC/student or group of 2 students / a projector/internet connection and software for processing earthquake data, software for data sonification.

Student's Misconception:

Students forge connections between sound and earthquakes, considering their wave nature. This way, they understand the similar characteristics of waves and waveforms and can work with parameters varying over time.

Before you start the activity

1. Presentation of the concept/ problem/ theory:

This is an 8 (didactical) hours educational activity that includes an introduction to earthquakes, the operation of a seismometer, the characteristics of the waveform, the features of a sound, the sonification process, the experimentation with accurate data, and the composition of the final product through cooperation with peers.

Teacher support:

The teacher will provide the students with preliminary material and is advised to discuss it with them before the beginning of the activity.

Evaluation:

Introductory material and questionnaires addressing the basic needs of the exercise will be offered to the students to explore before the beginning of the training.

Educational Phase



Discussion:

- Introduction to earthquake scales: Richter and Mercalli and symbolic sonification by using the sound of a known phenomenon of similar energy output to describe earthquakes of a specific magnitude scale.
- Presentation of actual earthquake data and discussion of their fundamental characteristics in frequency and amplitude.
- Presentation of the method scientists employ to find the earthquake epicenter using information from earthquake waveforms—interactive demonstration using online interactive maps.
- Using the time compression technique and identification of S- and P- waves, sonification of real earthquake data using auditory means. Students divide into groups and sonify the data of earthquakes to understand the time compression technique.
- Students discuss the frequency spectrum of sound and experiment with it to find out the boundaries of their hearing from infra to ultrasound. Students are provided with sonified data of an earthquake from different earthquake stations. They try to identify the earthquake epicenter by correlating the time difference of S- and P- waves they hear with epicenter distance.
- Comparison with the location of the epicenter measured using a visual description of data.

- **Stimulation**

- **Experimental activities:**

*Students discuss the fundamental characteristics of waves: Frequency, wavelength, propagation velocity, and amplitude. They discuss the differences between transverse and longitudinal waves and apply their knowledge to different waves. They discuss the nature of sound and identify the spectrum of human hearing, namely 20 Hz to 20kHz. By listening to different given sounds, they determine the frequency and amplitude of the sound.

*Students can work with these tools to learn more about sound's fundamental characteristics: <https://phet.colorado.edu/en/simulation/sound>

*Introductory lecture about earthquakes.

*Introduction to data sonification.

The Sound of the Earth

Students transform earthquake amplitude to frequency and then musical notes



Consolidation

Follow-up activity 1: Students work further with data sonification to correlate earthquake amplitude with the musical scale notes. Using the data obtained over a long time from a station, students synthesize the music of earthquakes.

Follow-up activity 2: Students create a performance using sonified earthquake data.

Follow-up activity 3: Students develop an algorithm that can transform the real-time data stream of a seismic station to music. Students will understand when an earthquake has started by listening to the changes in the sound produced by the P-waves. Such applications could help the in-time evacuation of buildings, prevention of aircraft landing, or stopping of trains before the most catastrophic S- and Love waves of an earthquake reach a specific territory.

Annexes with instructions

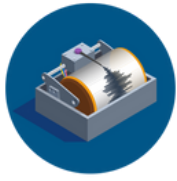


Annex 1 - Instructions, instruments, and materials for the vertical Slinky seismometer

Annex 2 - Instructions, instruments and materials for Print your own Shake Table and Build a better wall

Annex 3 - Instructions, instruments and materials for How to estimate the magnitude of seismic shocks by comparison

Annex 4 - Instructions, instruments and materials for Finding the velocity of P waves using real data collected from SEISMO-Lab seismometers



SEISMO-LAB

Annex 1 - Instructions, instruments, and materials for the vertical Slinky seismometer



INTRODUCTION

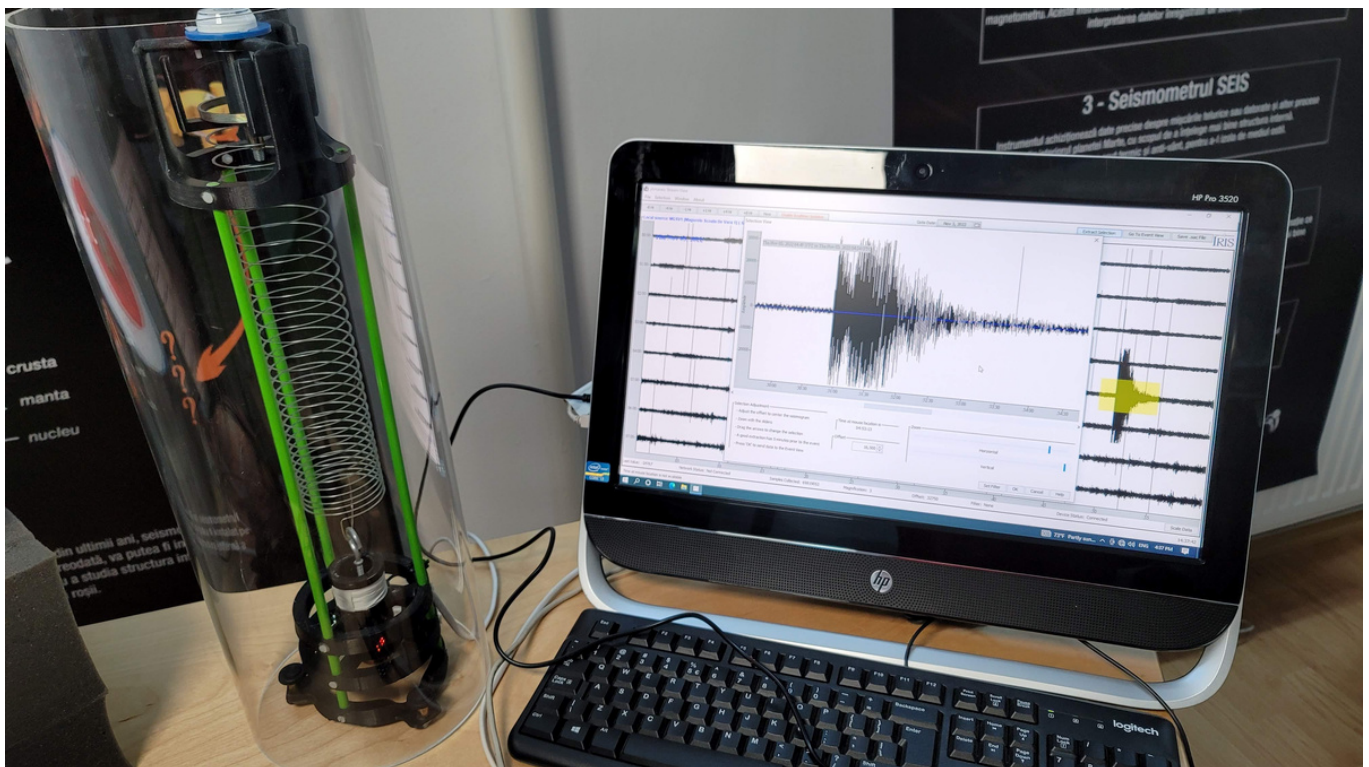
An earthquake is a natural phenomenon characterized by the sudden release of energy accumulated in rocks.



This energy is transmitted in the form of seismic waves that cause ground motion. The ground motion is recorded by seismometers which are based on electromagnetic induction.

The Slinky Vertical Seismometer stands out as one of the easy-to-build educational seismometer models. The kit offers an inexpensive solution to earthquake detection. The seismometer uses electromagnetic induction to detect ground motion and incorporates eddy current damping for improved detection.

Supplied as a kit, the seismometer is easy to assemble and it will be up and running in a short time!



Assembling and installing a Slinky seismometer



Necessary materials:

1. Slinky - Ø 58 mm -
1 piece



2. PLA.stl picese - 5 pieces of each type

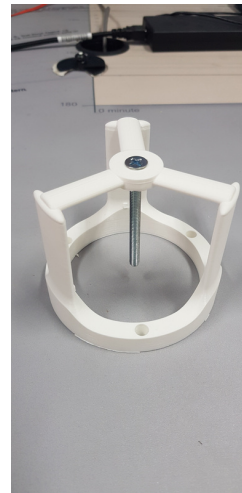
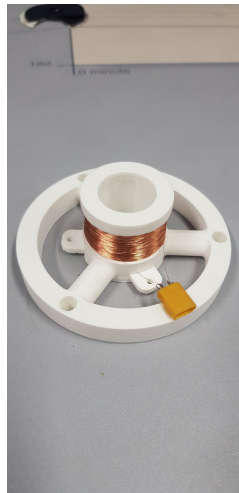
1. BaseRing

2. DamperRetainerRing

3. WireSpoolRing

4. ExtendedTopCap

5. SlinkyRetainer

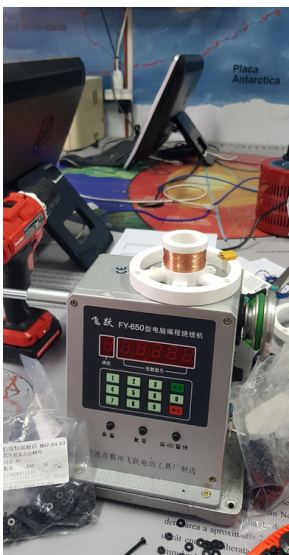


3. Copper coil -
Ø 0,10mm Cu wire; ~3500
spirals => ~ 620 Ω
1 piece

4. Rigid acrylic tube
Ø 165 mm; H 50 cm
1 piece

5. Fiberglass supports
L 400 mm; 7 mm
3 pieces

6. Adjustable metal legs
M4 x 25
3 pieces





Necessary materials - sequel:

7. Level bubble
circular
1 piece



8. Neodymium
magnet
Ø 14mm; H 8 mm
1 piece



9. Neodim magnet
Ø 10mm; H 5mm
1 piece



10. Threaded screw for distance
between magnets
M4
1 piece



11. Copper damping
Reduction from
Ø 28 mm to Ø 22 mm
1 piece



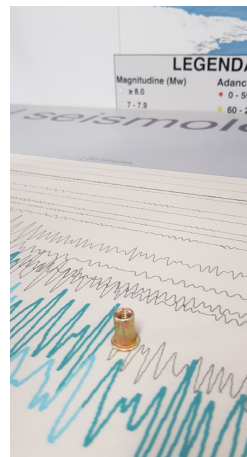
12. Threaded hook
for magnet suport
Ø 4 mm; L 60 mm
1 piece



13. Threaded screw
M6
L 60 mm
1 piece



14. Rivet nut
1 piece M6
3 pieces M4



15. Round steel washer
M6 x Ø 20 mm
1 piece



16. Plastic screw
M2,5 Ø15mm
15 pieces



17. Super Glue
Transparent
1 piece



STAGE 1. CREATING PLA PIECES

Making PLA parts on a 3D printer:



To make the parts for the Slinky seismometer, use the ULTIMAKER 3 Extended printer and the Ultimaker Cura parts calibration program ([click here to download](#)).

We have a total of 5 pieces that must be made as follows:

Nr. Crt	Name	Material	Rezolution (mm)	Infil (%)	Duration (hours)	Quantity (g)	Length of the material (m)	Filament thickness (Ø/mm)	Zoom (%)
1	BaseRing	PLA	0,1	25	5:00	26	3,26	2,8	0
2	DamperRetainerRing	PLA	0,1	25	6:40	35	4,44	2,8	0
3	WireSpoolRing	PLA	0,1	25	8:00	44	5,53	2,8	0
4	ExtendedTopCap	PLA	0,1	25	9:00	49	6,18	2,8	0
5	SlinkyRetainer	PLA	0,1	25	3:40	17	2,10	2,8	4200

These are the basic parts for making the Slinky seismometer.

In the [STL file here](#), you have 2 more additional pieces that you can add if you want.

STLs can be modified depending on the materials purchased, the characteristics in the table above are for the materials used in this seismometer.



STAGE 2. ASSEMBLING THE SLINKY COVER WITH ITS RELATED ACCESORIES



Accessories:

- Slinky support
- Slinky
- M4 Countersunk head screw
- M6 rivet nut
- M4 Steel washer
- Level bubble
- M3 plastic screws (3 pcs)

Tools:

- Electric screwdriver, screwdriver for threading screws;
- $\varnothing 2,5$ mm drill for metal;
- Pliers;
- Marker

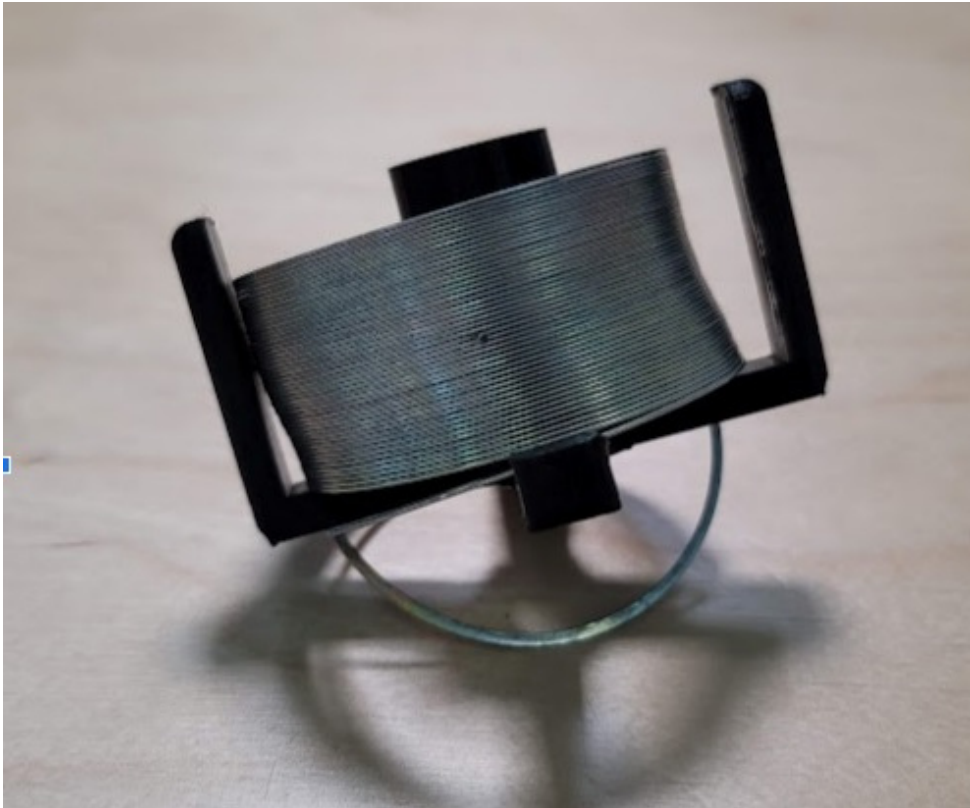


STEP 1: THE SCREW WILL BE INSERTED THROUGH THE SLINKY COVER



STEP 2:

- THE SLINKY IS BENT AT ONE END AT AN ANGLE OF 90 DEGREES;
- TAKE THE SLINKY SUPPORT AND INSERT THE ALREADY BENT SPRING INTO IT, AFTER WHICH IT ROTATES TO THE RIGHT THROUGH THE SUPPORT SO THAT THE SPRING CAN EASILY PASS THE 4 RODS OF THE SUPPORT (SEE THE FOLLOWING IMAGE)



STEP 3: TAKE THE SUPPORT WITH THE SPRING IN IT, WHICH IS INSERTED THROUGH THE M6 SCREW, THREADING THE RIVET NUT BY INCORPORATING UNTIL THE SUPPORTS ARE FIXED BETWEEN THEM



STEP 4:

- THE ROUND BUBBLE WILL BE PLACED ON THE SLINKY COVER. MARK ITS HOLES WITH A MARKER. REMOVE THE BUBBLE AND GIVE THREE HOLES WITH THE HELP OF A THREAD IN WHICH WE HAVE INSERTED A METAL DRILL WITH A DIAMETER OF 2.5 MM;
- AFTER THE HOLES ARE GIVEN, THE BUBBLE WILL BE ATTACHED TO THE COVER, AND THE SCREWS WILL BE TIGHTENED TO FIX IT.



STAGE 3. ASSEMBLING THE DAMPING SUPPORT WITH ITS RELATED ACCESSORIES



Accessories:

- Damping support
- Copper damping
- SuperGlue

Tools:

- Gloves



STEPS:

- For your protection, use gloves.
- Insert the attenuator with the broader end into its support, exceeding the end of the attenuator by approximately 5mm.
- Fix the support attenuator with Super Glue.
- Let it dry for 30 minutes.



STAGE 4. ASSEMBLY OF THE COIL ON ITS SUPPORT

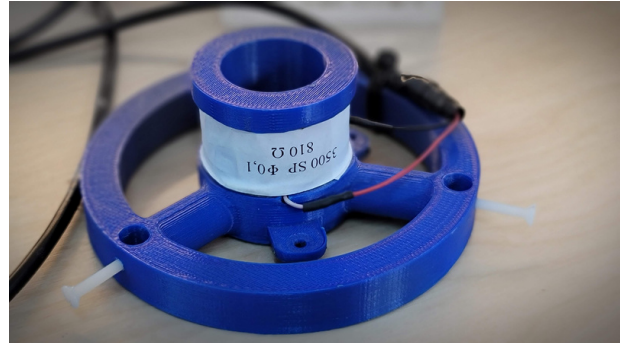


Accessories:

- Coil support;
- Copper wire: $\varnothing 0.10$ mm = ~ 100 gr. weight;
- Stranded electric cable 2x1 mm = ~ 60 cm lengths;
- Paper tape;
- Insulating tape or heat-insulating tubes

Tools:

- Soldering machine with paste and flux;
- Cable crimping pliers or a cutter.



STEPS:

- TAKE THE COIL SUPPORT AND THE END OF THE WEFT THREAD AND LEAVE THE LOT OUTSIDE THE SUPPORT APPROXIMATELY 10CM;
- START FORMING THE COIL BY MAKING APPROXIMATELY 3500 - 4000 TURNS AROUND THE COIL SUPPORT;
- AFTER FINISHING THE WINDING COIL, THE ELECTRIC CABLE WILL BE TAKEN, AFTER WHICH WE WILL GLUE THE ENDS OF THE COIL WITH THE HELP OF THE SOLDERING IRON;
- AFTER THAT, WE ISOLATE THE SOLDERS UNTIL THEY ARE CLOSE TO ITS SUPPORT;
- FINALLY, WE ALSO ISOLATE THE COIL WITH PAPER TAPE TO PROTECT IT SO IT DOES NOT UNFOLD.



STAGE 5. ASSEMBLING THE SUPPORT OF THE BASE



Accessories:

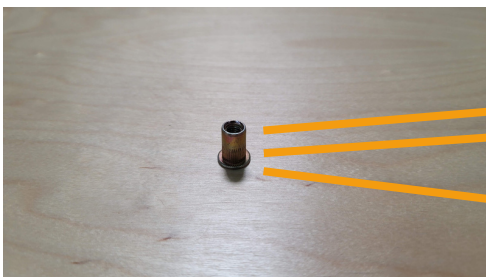
- Rivet type nut;
- Adjustable metal legs;
- SuperGlue

Tools:

- Gloves

STEP 1:

- TAKE THE LEG SUPPORT AND THE THREE RELATED NUTS
- THE SUPPORT WILL BE POSITIONED AS IN THE IMAGE WITH THE THREE CURVES DOWN; IT WILL BE GIVEN WITH SUPERGLUE ON THE INSIDE OF THE NUT EAR IN SUCH A WAY THAT WHEN WE INSERT IT, THE GLUE ON THE NUT MAKES CONTACT WITH THE SUPPORT.
- INSERT THE THREE NUTS INTO THE THREE EARS OF THE SUPPORT.



STEP 2: AFTER FIXING THE NUTS, THE LEGS WILL BE THREADED INTO THE NUTS AS IN THE ATTACHED IMAGE



STAGE 6. ASSEMBLING THE SLINKY SEISMOMETER



Accessories:

- Fiberglass supports;
- The four supports that were equipped with accessories at the above stages;
- M4 magnets support;
- 3cm threaded screw for the distance between magnets
- Disc neodymium magnet \varnothing 10mm; H 5 mm
- Disc neodymium magnet \varnothing 14mm; H 8 mm
- M3 Plastic screws
- M4 Two nuts

Tools:

- Electric screwdriver, screwdriver head for threading screws;
- \varnothing 2,5 mm metal drill;
- Ruler;
- Pliers;
- Marker



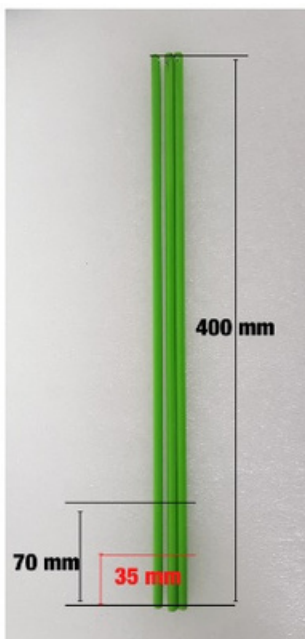
STEP 1:

- THE SUPPORT WILL BE MOUNTED ON THE BASE OF THE 3 FIBERGLASS SUPPORTS
- THEY WILL BE CUT TO A LENGTH OF 40CM

STEP 2. FROM ONE END OF THE 3 SUPPORTS, MEASURE 35 MM, RESPECTIVELY 70 MM AND SIGN (ON THOSE SIGNS THE COIL SUPPORT AND THE ATTENUATOR SUPPORT WILL COME LATER)

THE FIRST SUPPORT WILL ENTER THE ONE WITH THE COIL, MEASURING 70 MM BELOW IT.

THE SECOND WILL ENTER THE SUPPORT WITH THE ATTENUATOR, THIS HAVING 35 MM TO THE BOTTOM



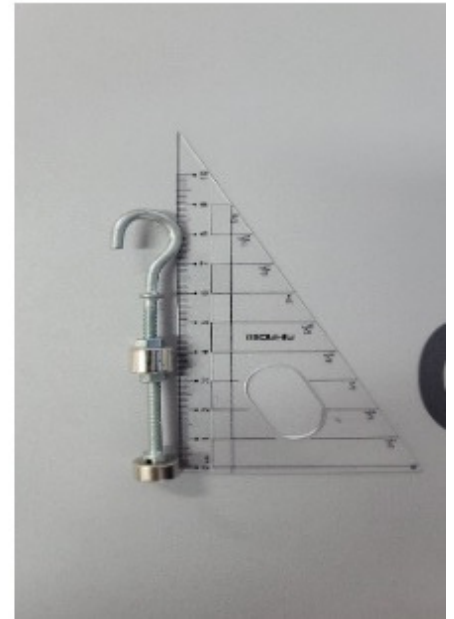
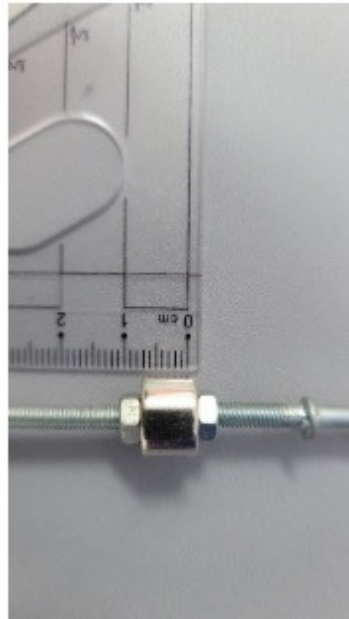
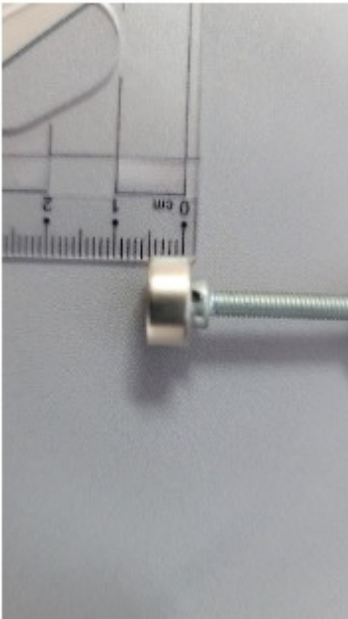
STEP 3:

- THE THIRD WILL ENTER THE SUPPORT WITH METAL LEGS, THIS BEING INSERTED EXACTLY IN THE GROOVE OF THE FIBERGLASS SUPPORTS
- THE FOURTH COVER WILL BE INSERTED IN THE UPPER PART, AFTER WHICH WE WILL UNROLL THE SPRING SO THAT IT HANGS SLIGHTLY OVER THE HALF OF THE FIBER LEGS OF 40CM

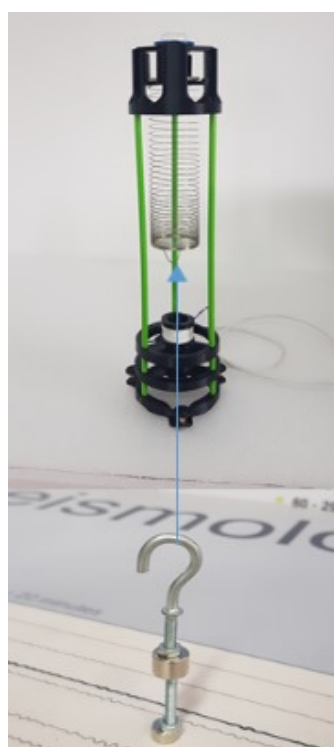


STEP 4: PREPARE THE SUPPORT WITH MAGNETS:

- THE SUPPORT WITH THE HOOK MUST BE 47MM, AND AT ITS END, A NUT IS THREADED, THIS NOT EXCEEDING THE SCREW OF THE HOOK
- NOW WE ATTACH THE 8 MM HIGH MAGNET TO THE NUT ATTACHED TO THE HOOK.
- WE WILL THREAD THE OTHER NUT ON THE END OF THE SCREW THAT HOLDS THE PLACE OF THE SPACER, TO WHICH WE WILL ATTACH THE 5 MM HIGH MAGNET.



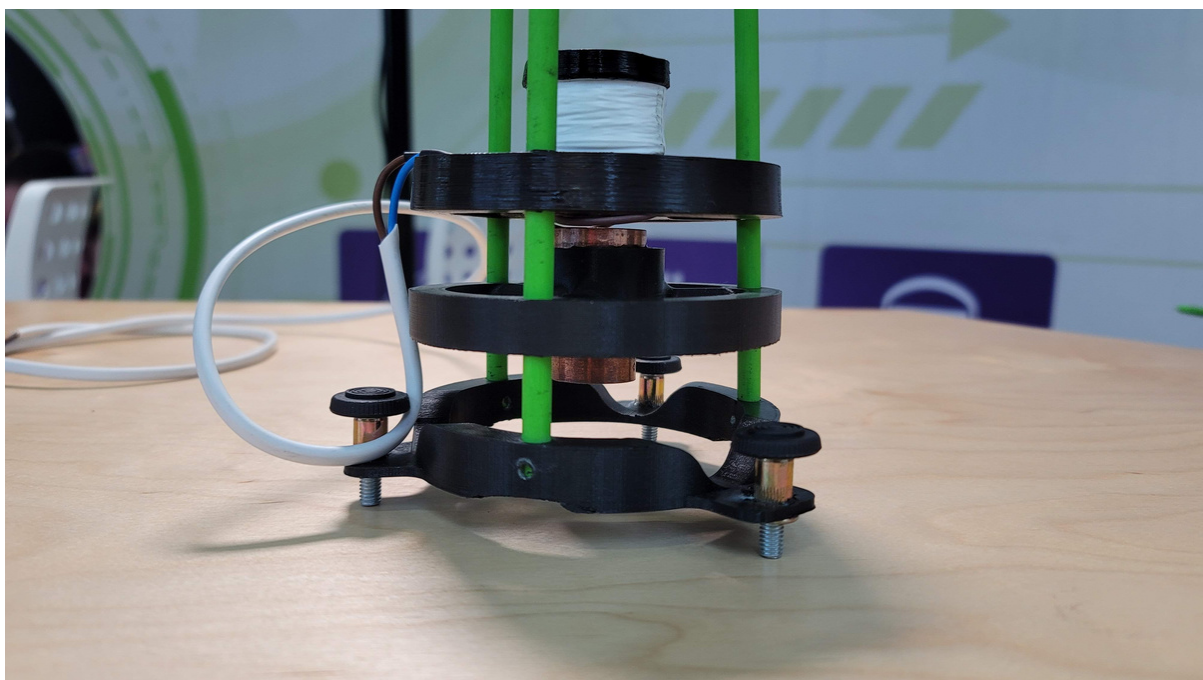
STEP 5: THE MAGNETIC HOLDER WILL CLING TO THE SPRING TAB (SEE THE FOLLOWING IMAGE)



STEP 6: NOW THE ELASTIC CONSTANT OF THE SPRING (SLINKY) WILL BE ADJUSTED SO THAT THE MAGNET HOLDER WILL DROP THE MAGNETS ONE ON THE COIL AND THE OTHER ON THE ATTENUATOR SO THAT THE MAGNETS ARE NOT STUCK TO THE ATTENUATOR



STEP 7: THE THREAD WILL BE TAKEN IN ITS CHUCK WITH THE METAL DRILL, AND A HOLE WILL BE DRILLED NEXT TO EACH CONTACT BETWEEN THE PLA SUPPORTS (BLACK) AND THE GLASS FIBER SUPPORTS (GREEN) - THERE ARE THREE HOLES ON EACH PLA SUPPORT, THERE WILL BE A TOTAL OF 12 SPOTS WHERE THE M3 PLASTIC SCREWS WILL BE INSERTED



STAGE 7. THE ANALOG – DIGITAL CONVERTOR (DIGITIZER)

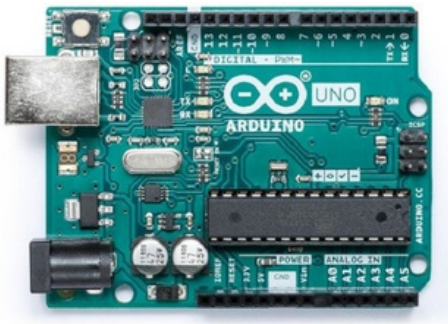
** is an electronic device that allows the real-time transfer of data to a computer**



Necessary materials

All components are generally ready to use except for the Adafruit ADS1115 ADC converter. Usually it is purchased without having the pin ruler glued on the conversion module. Thus, it is necessary to glue the ruler using a soldering hammer.

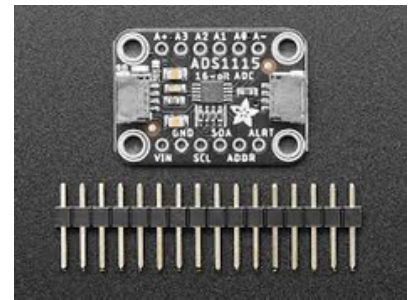
1. Arduino Uno development board
1 piece



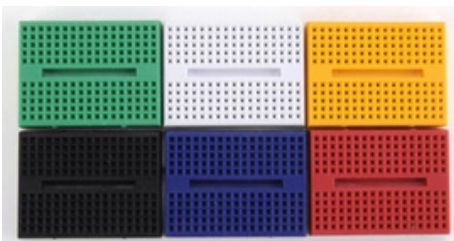
2. USB A-B cable
1 piece



3. Adafruit ADS1115 ADC converter
1 piece



4. Breadboard for circuits
1 piece



5. Father-father circuit wires
9 pieces



6. Soldering hammer and accessories
1 piece

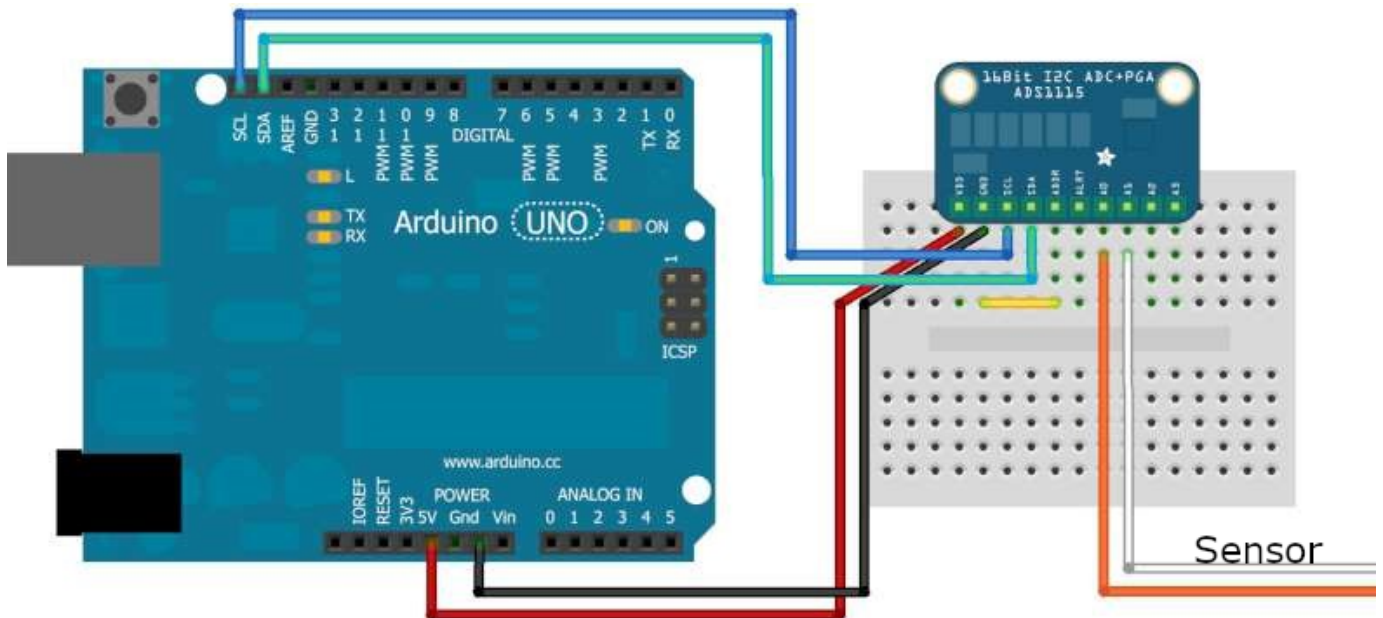


7. Arduino code:

https://drive.google.com/file/d/1cAPIpQgbMn8h4gktdvdLLhEeaQLEiE0k/view?usp=share_link

Installation diagram

To build the analog-digital converter (digitizer), the assembly from the diagram below is carried out:



A video tutorial with the work steps to be followed to connect the Slinky/ TC1 seismometer to the jMaseis educational program via the Arduino Uno digitizer with ADS1115 Adafruit converter can be downloaded here:



https://drive.google.com/file/d/1RfTzGEp6d3b5yqBH6yjGmc40Aw_g0T1j/view?usp=share_link

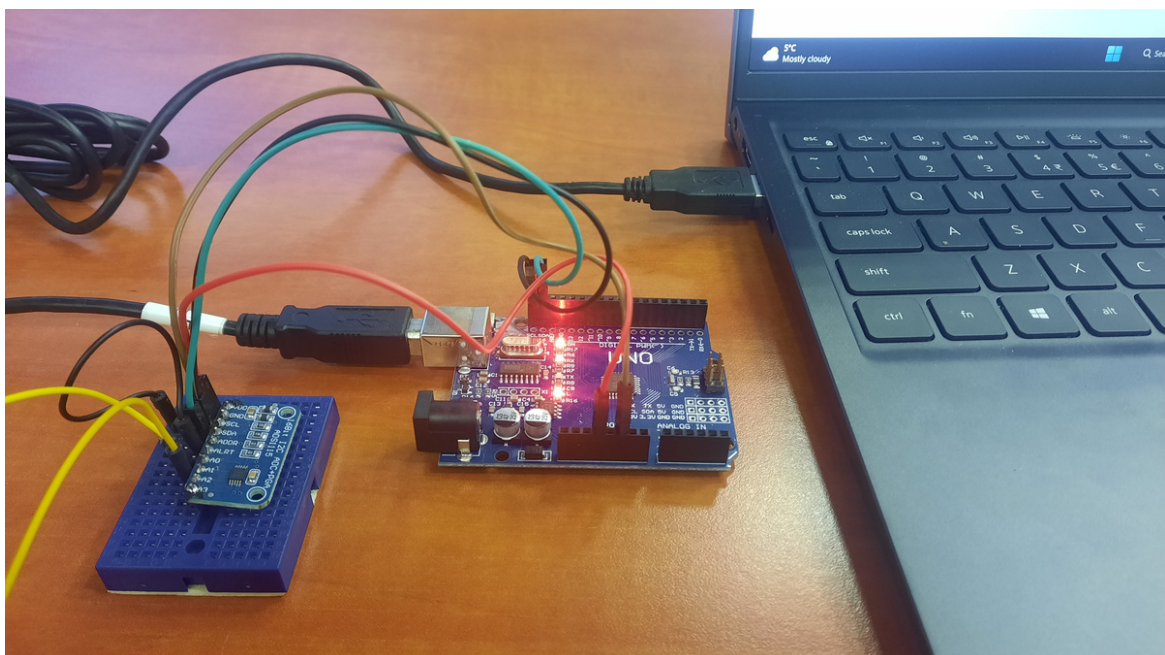
Also, the code for digitizer can be downloaded from here:

https://drive.google.com/file/d/1cAPlpQgbMn8h4gktdvdLLhEeaQLEiE0k/view?usp=share_link

Once the assembly is completed, it must be connected to a computer with Arduino Software (IDE) open-source installed to load the code into the Arduino Uno microcontroller.

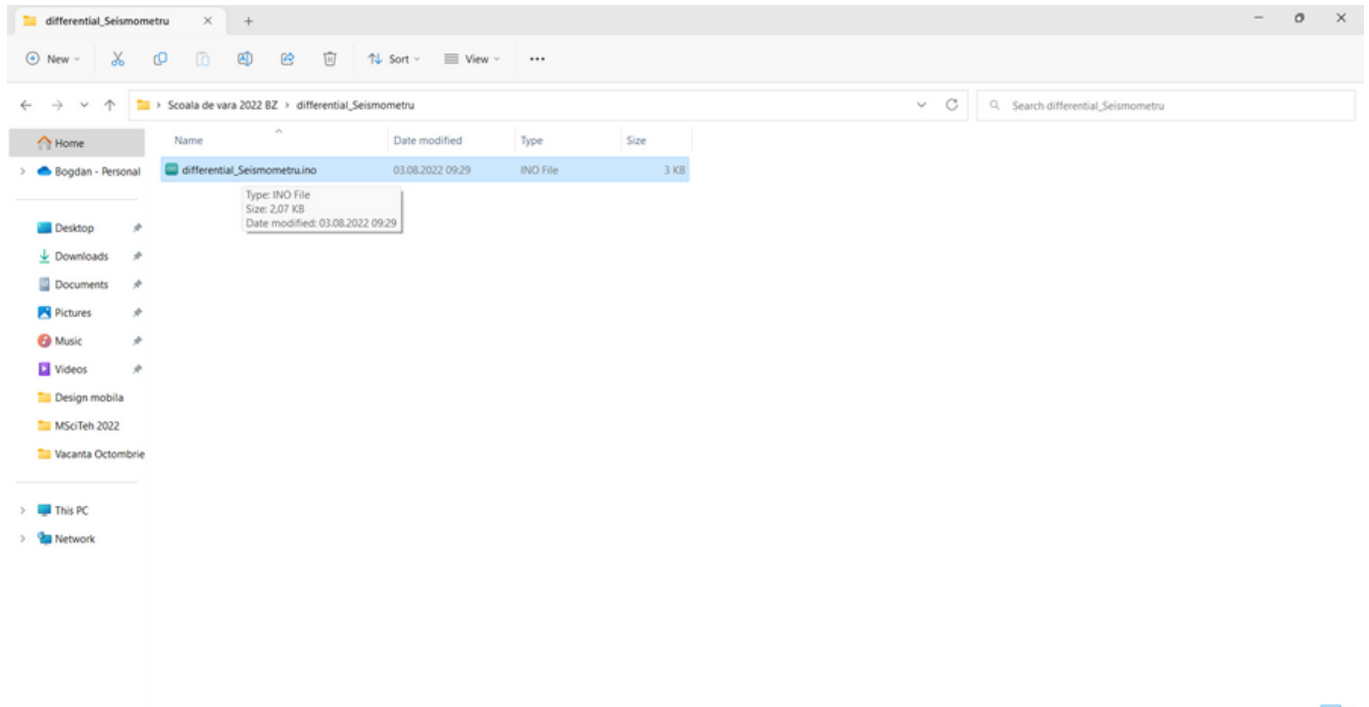
Arduino Software (IDE) can be downloaded and installed here: <https://www.arduino.cc/en/software>.

Connect the mount to the computer's USB port:

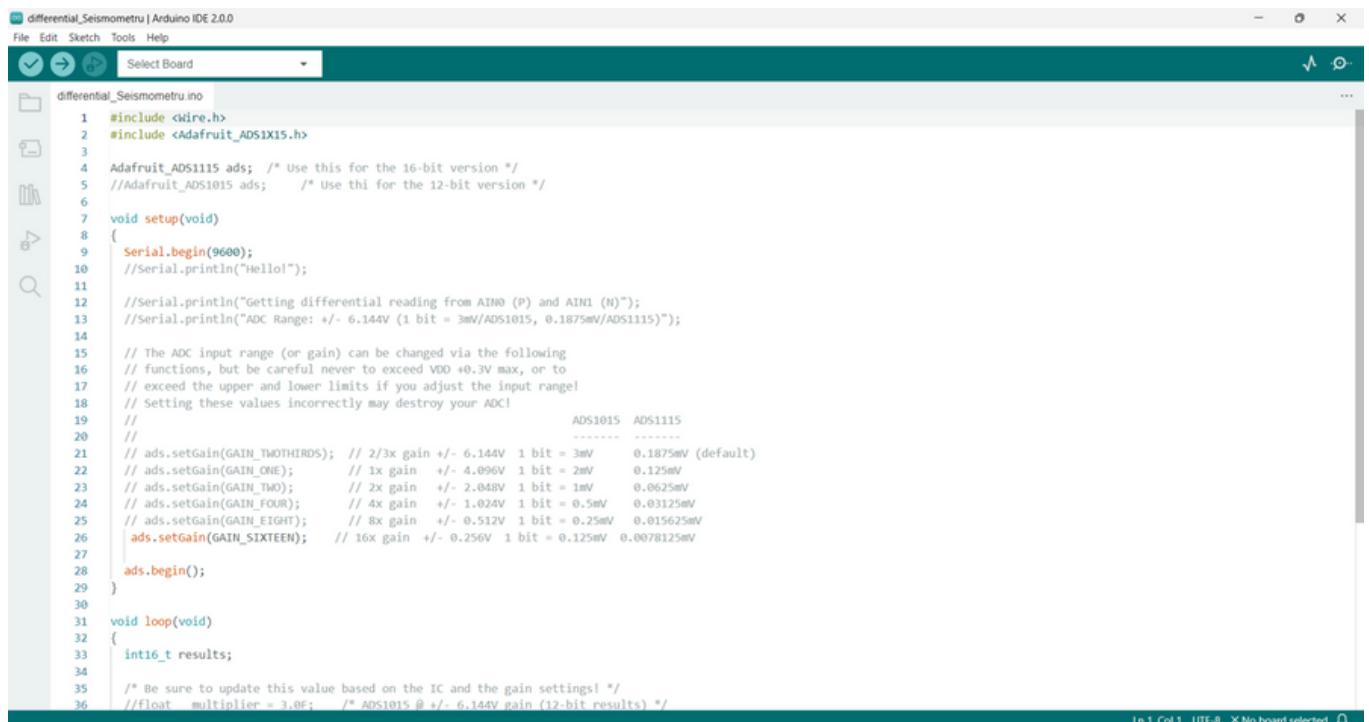


From this moment on, go through the following steps to load the code into the Arduino microcontroller:

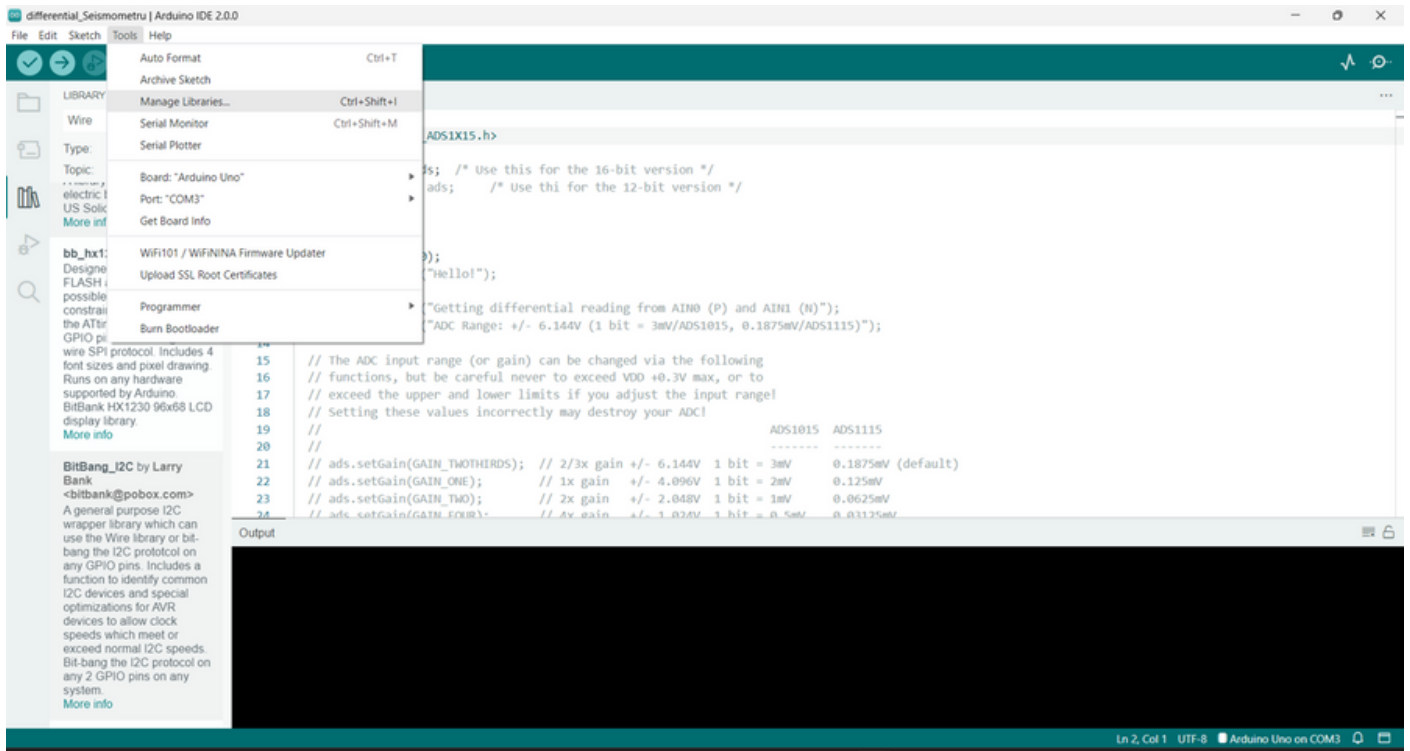
STEP 1: OPEN THE ARDUINO CODE DIFFERENTIAL_SEISMOMETRU.INO



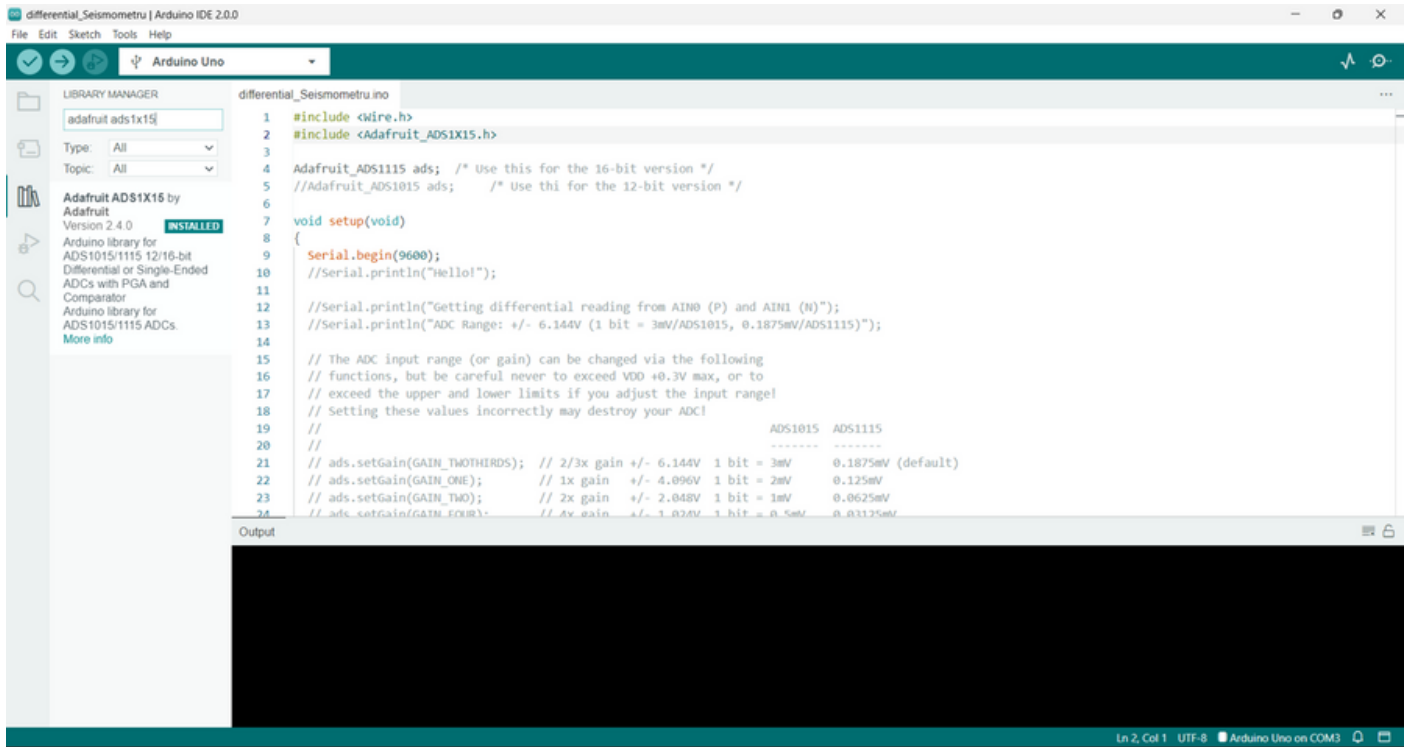
STEP 2: THE FIRST 2 LINES OF THE CODE CONTAIN THE NAMES OF THE LIBRARIES (THEY CONTAIN INFORMATION ABOUT THE ADAFRUIT ADS1115 CONVERTER AND THE DATA TRANSMISSION MODE) THAT MUST BE INSTALLED:



STEP 3: GO TO TOOLS/ MANAGE LIBRARIES...



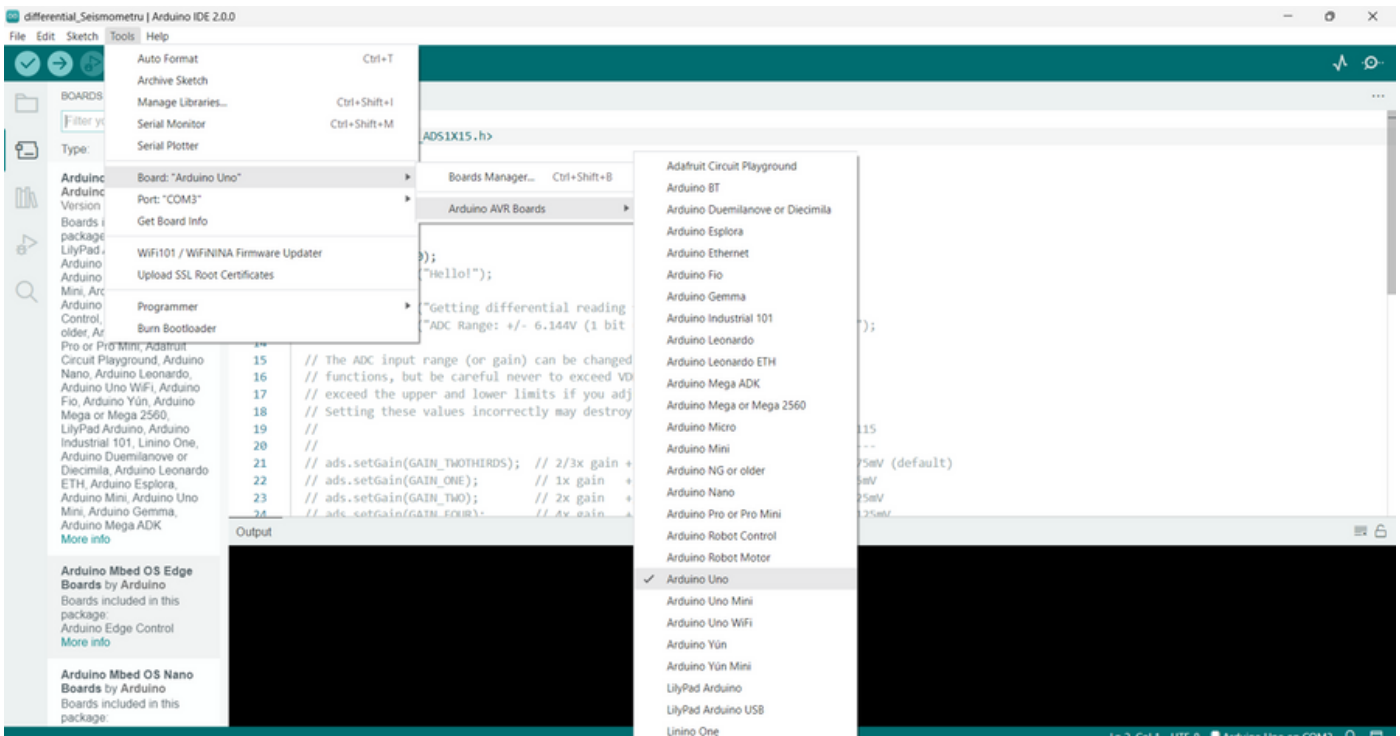
STEP 4: WE ARE LOOKING IN THE LIBRARY MANAGER FOR THE ADAFRUIT ADS 1X15 LIBRARY FOR OUR CONVERTER



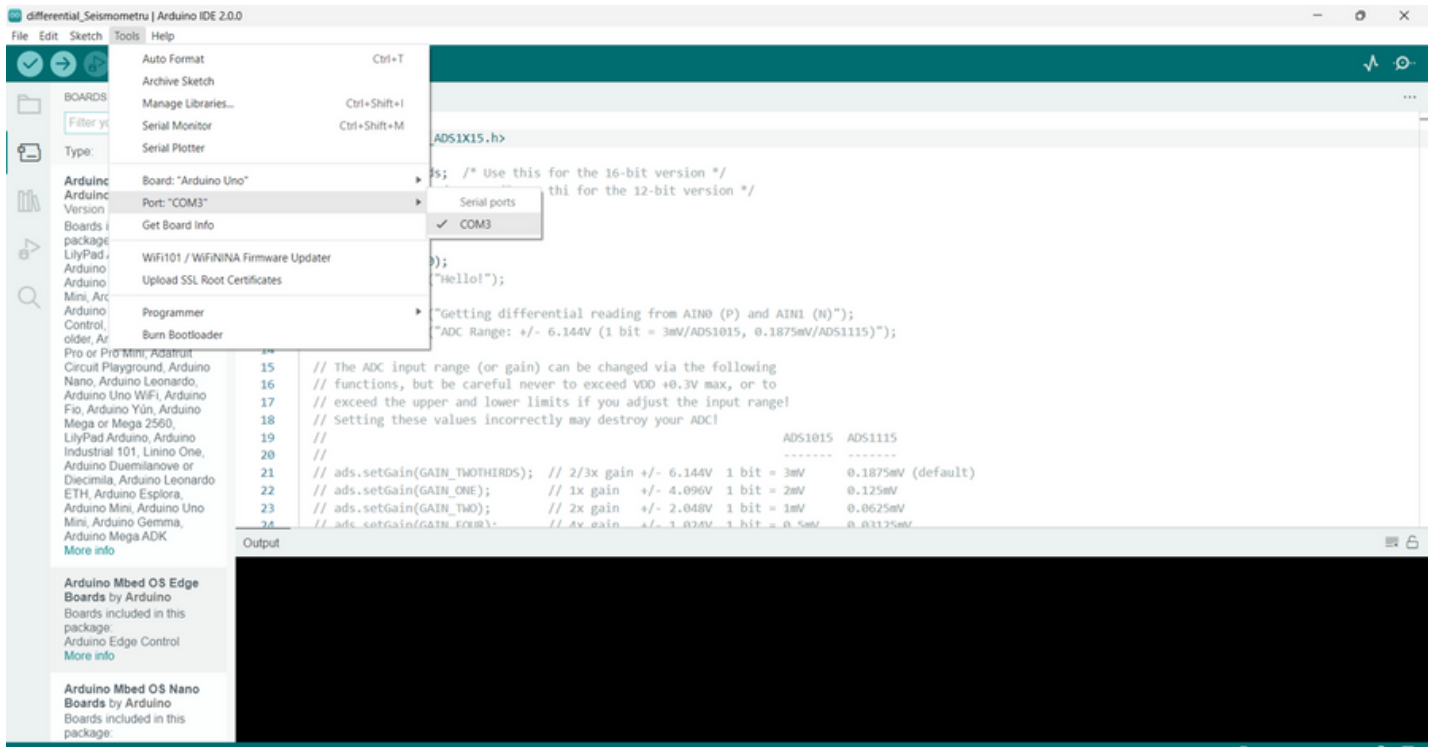
STEP 5: IN THE PRESENTED SITUATION, THE LIBRARY WAS ALREADY INSTALLED. TO INSTALL IT, PRESS THE INSTALL BUTTON.

STEP 6: THE PROCEDURE IS THE SAME FOR THE WIRE LIBRARY

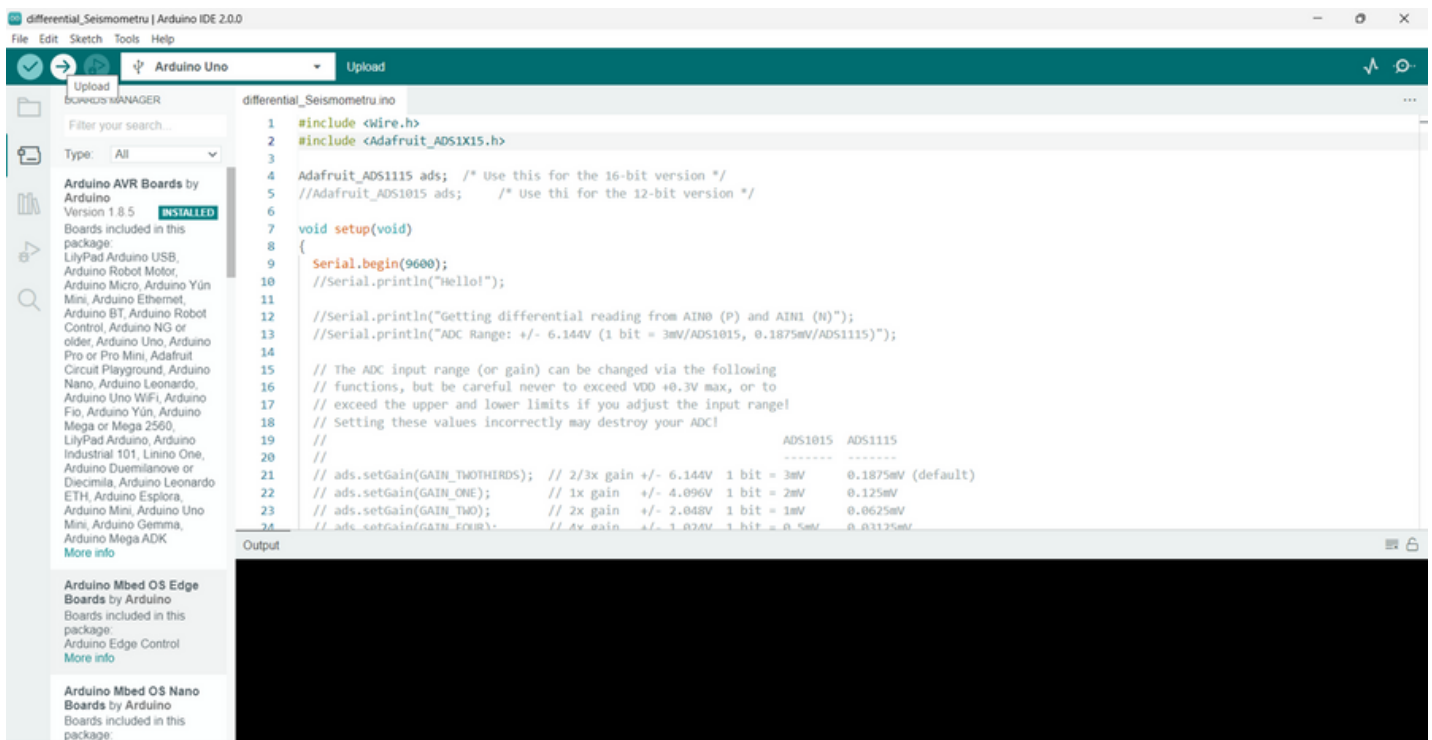
STEP 7: AFTER INSTALLING THE LIBRARIES, WE SELECT THE ARDUINO BOARD WE WERE WORKING WITH. IN OUR CASE IT IS ARDUINO UNO. GO TO TOOLS/ BOARD:...../ARDUINO AVR BOARDS/ ARDUINO UNO



STEP 8: WE CHECK THE COMMUNICATION PORT BY ACCESSING THE MENU TOOLS/ PORT:..... IN OUR CASE IS COM3



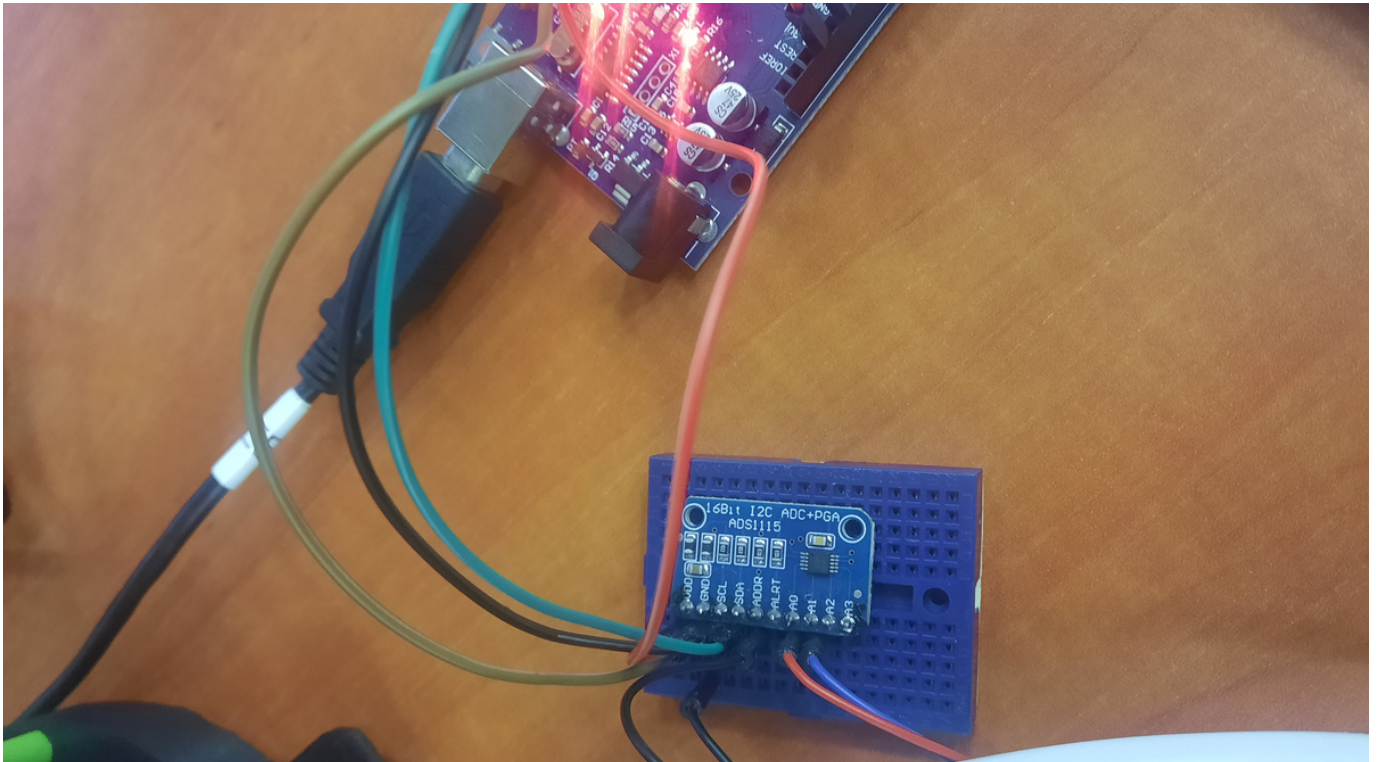
STEP 9: NOW WE CAN LOAD THE CODE INTO THE ARDUINO MICROCONTROLLER:





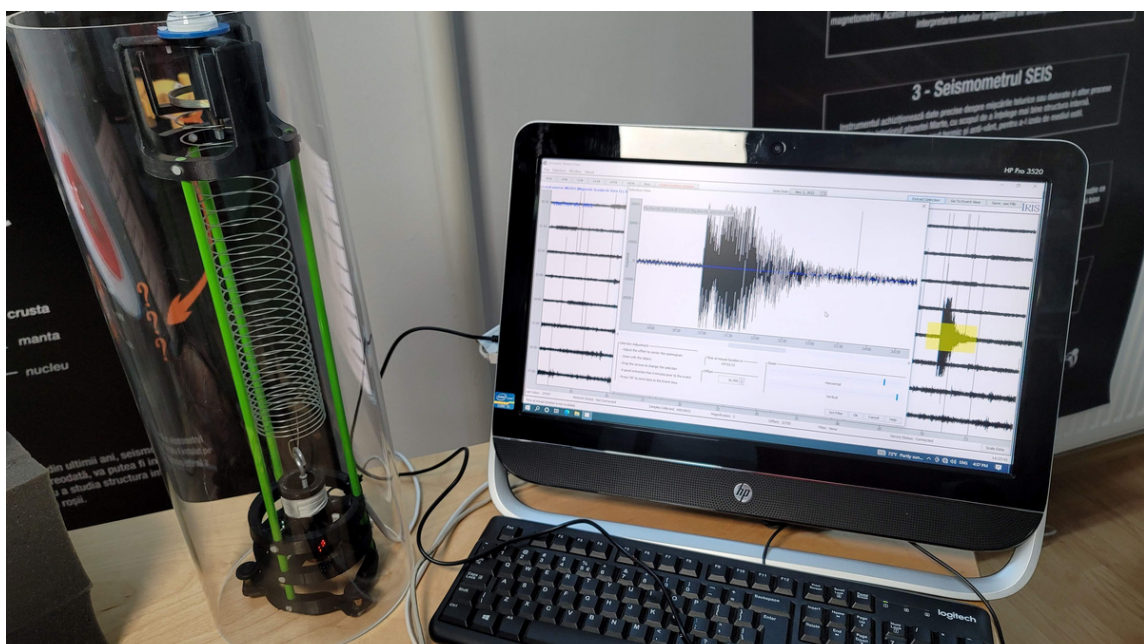
If the libraries have been installed correctly and the code loaded into the microcontroller, you can proceed to connect the seismometer to the computer. Then, into the microcontroller, you can move to join the seismometer to the laptop. Into the microcontroller, you can proceed to connect the seismometer to the computer. Then, into the microcontroller, you can move to join the seismometer to the laptop. From this moment, the Arduino IDE platform can be closed.

We make sure that the 2 wires from the seismometer coil are connected to pins A0 and A1 of the Adafruit ADS1115 converter:



In the present case, seismometer data is acquired with the jAmaseis educational program. It can be downloaded for free from <https://www.iris.edu/hq/jamaseis/>

The program installation procedures and connecting the seismometer are also described here. In the end, we will have an "educational seismic station" consisting of TC-1 educational seismometer, Arduino digitizer with ADS1115 converter, and a jAmaseis data acquisition program:





Annex 2 - Instructions, instruments and materials for Print your own Shake table and build a better wall



INTRODUCTION

This tutorial is a critical component of the SEISMO LAB project. It focuses on participatory, inclusive, cross-curricular learning challenges and engages students in activities that will increase their problem-solving skills and stimulate creativity.

Following this tutorial, students will reinforce their skills in using a 3D printer, enhance their technical abilities by assembling the shake table, and develop critical thinking by building and testing an earthquake-resilient structure. In addition, the workgroup will participate in meaningful and motivating science inquiry activities on earthquake disaster mitigation and will find and implement structural solutions to improve a building's response to the horizontal component of a seismic wave.

This demonstrator is meant to help teachers enlarge the range of STEAM activities implemented in science classes where students learn, practice, and utilize scientific instruments and methods while improving communication skills as they present the outcomes of their work.

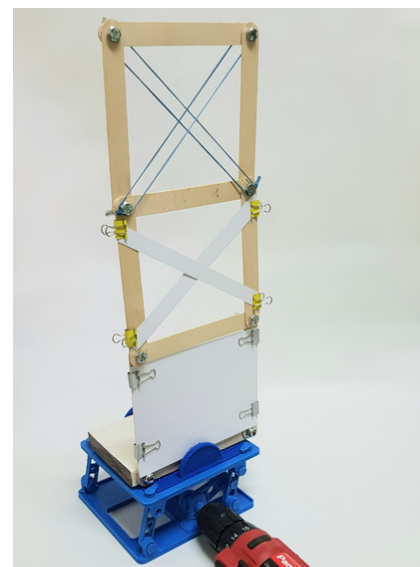
The following tutorial is elaborated as a step-by-step guidebook and is structured in two stages:

1

Printing a shake table, using a 3D printer, and assembling it. Students improve their technical skills and critical thinking.

2

Building a structure, testing it on the shake table, and finding solutions to enhance its response to an earthquake. Students need to discover how different connections strengthen a structure to carry forces resulting from earthquake shaking.



STAGE 1. PRINTING AND ASSEMBLING A SHAKE TABLE

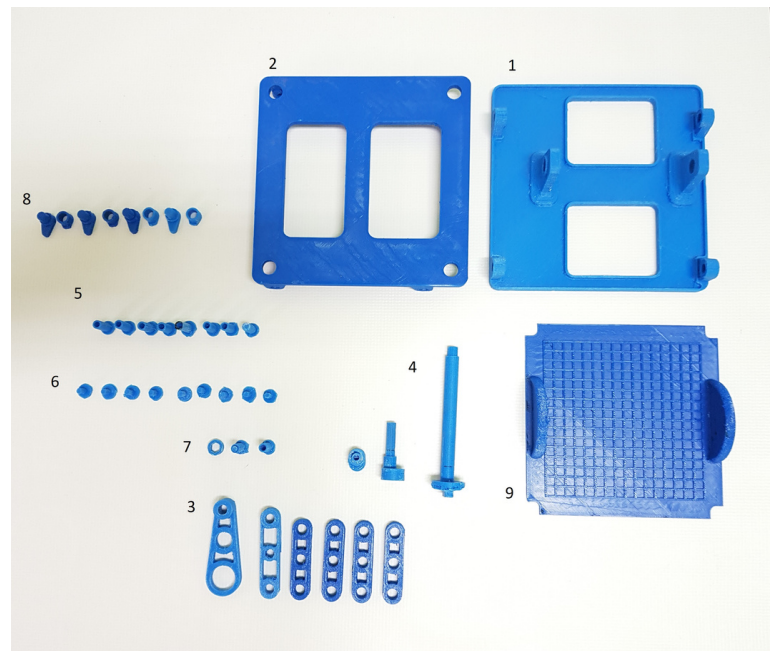
STEP 1: PRINT YOUR SHAKE TABLE COMPONENTS USING THE FOLLOWING OPEN-SOURCE PROJECT:

 [Open-source project](#)



Necessary materials:

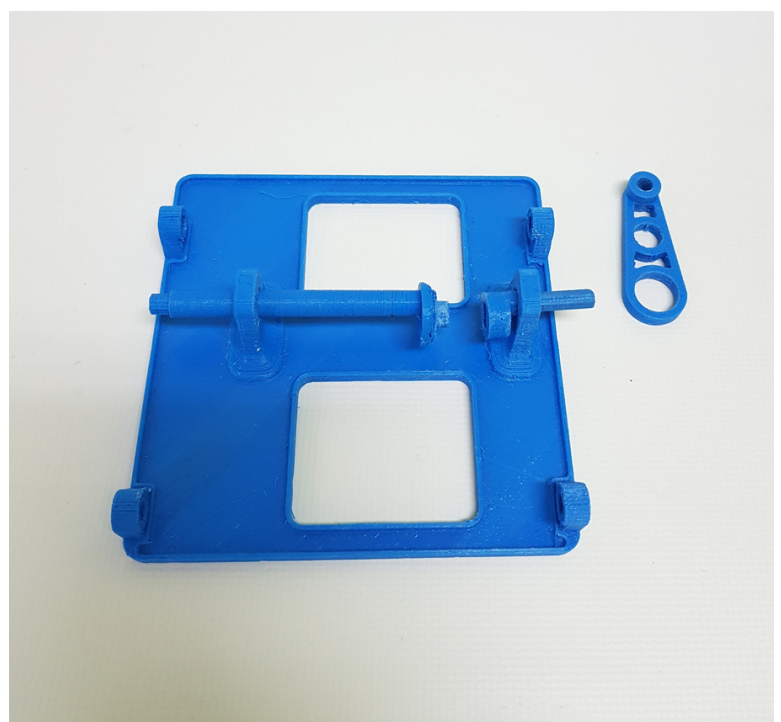
1. Base plate – 1 pc
2. Top plate – 1 pc
3. Transmission gear – small 4pcs, medium 1 pc, eccentric 1pc
4. Main axis – 1 pc of each component
5. Screws – 10 pcs
6. Pins – 10 pcs
7. Bolt nut – a pc
8. Top plate lock – 4 pcs of each (top and bottom stopper)
9. Top testing plate – 1 pc



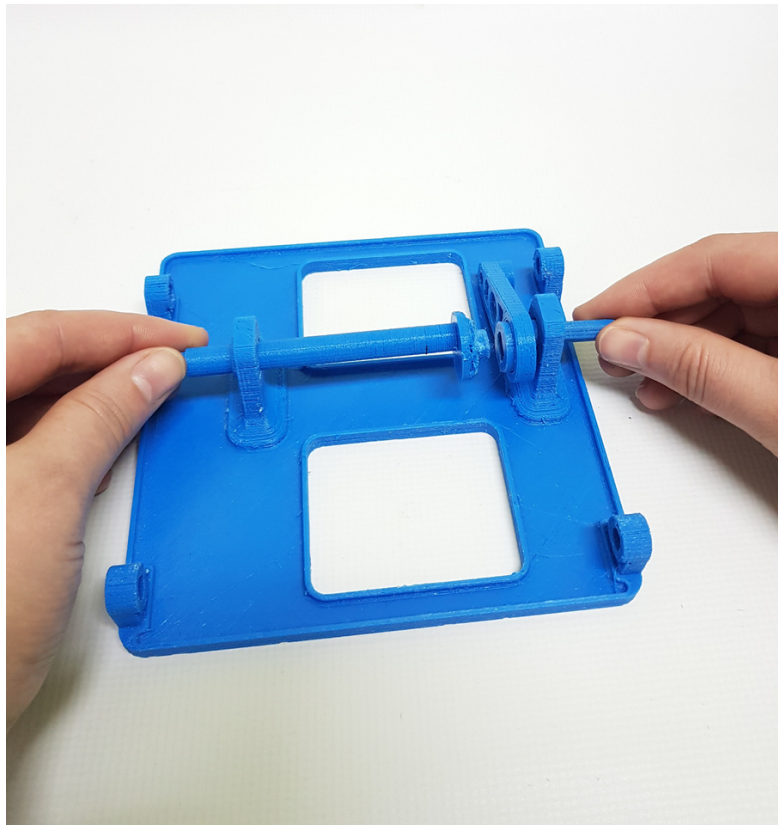
STEP 2: START ASSEMBLING YOUR SHAKE TABLE

Start with fixing the main axis (4) on the base plate (1).

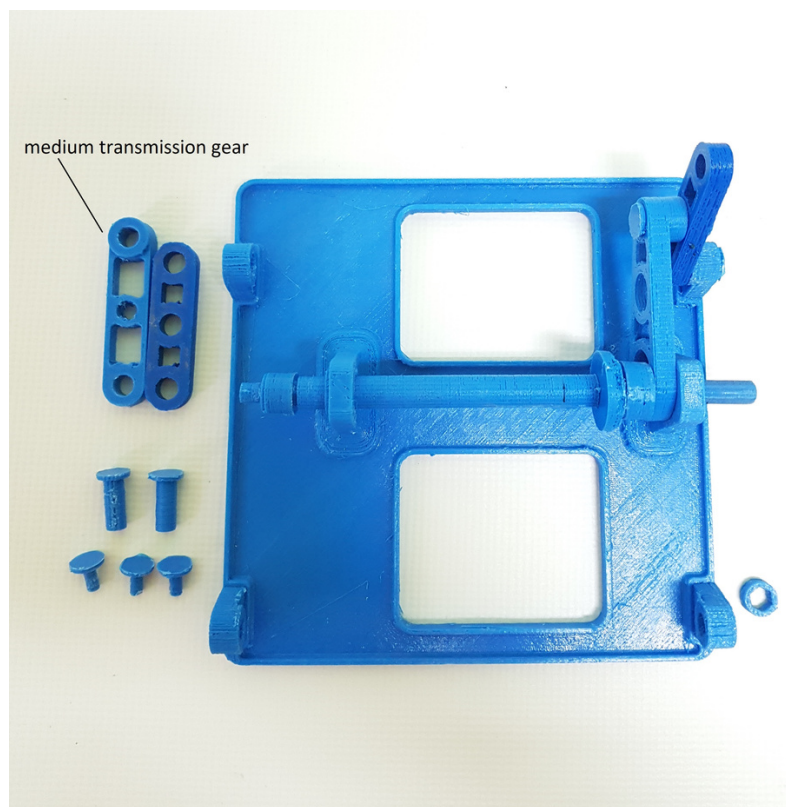
Leave the last connection open in order to insert the eccentric gear (3).



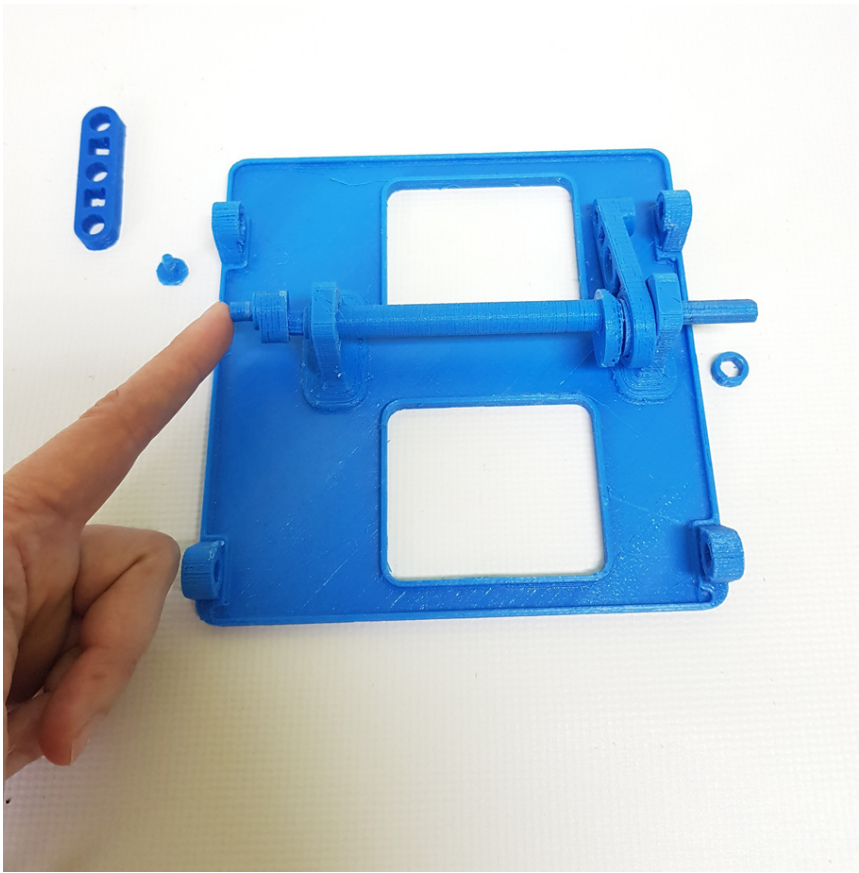
STEP 3: INSERT THE ECCENTRIC GEAR AND CONNECT THE MAIN AXIS.



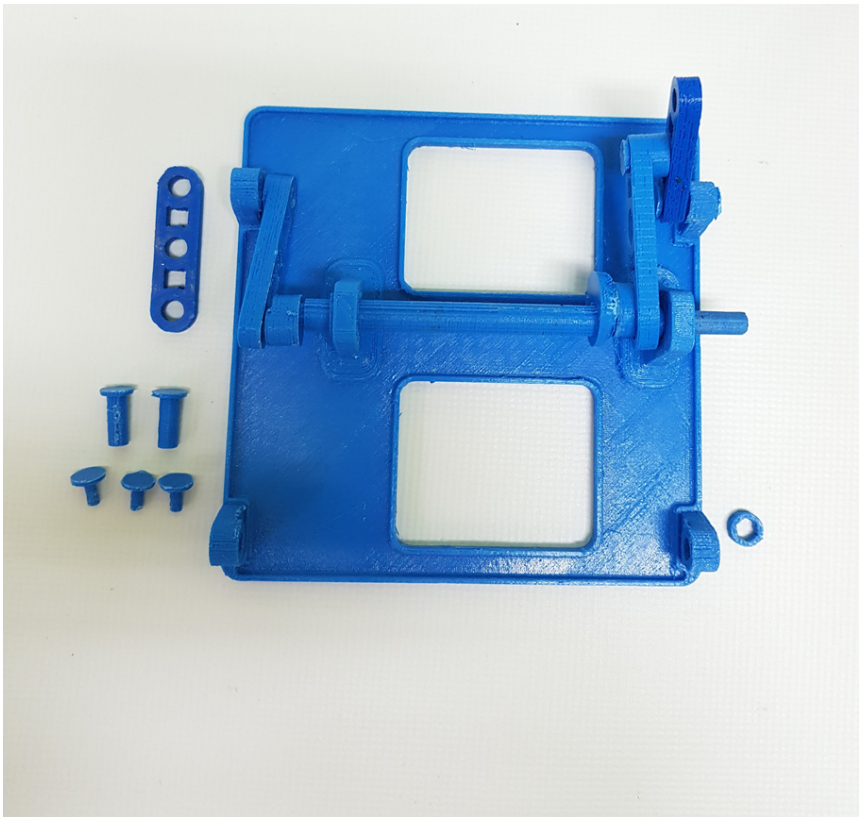
STEP 4: PREPARE THE AXIS PIN (4), ONE SIMPLE PIN (6) AND THE MEDIUM TRANSMISSION GEAR (3)



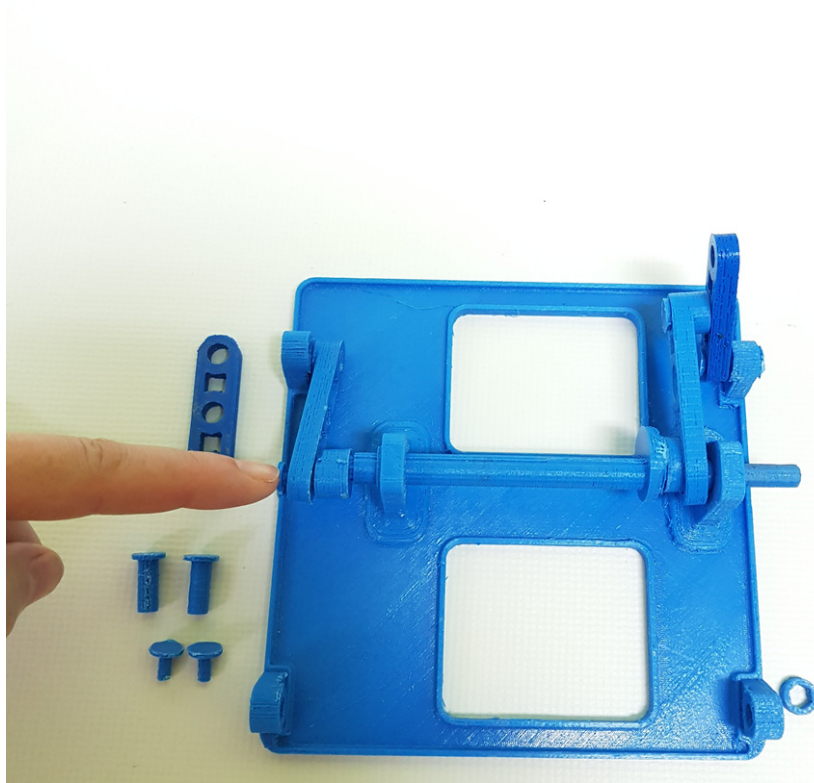
STEP 5: PUSH THE AXIS PIN INTO THE MAIN AXIS



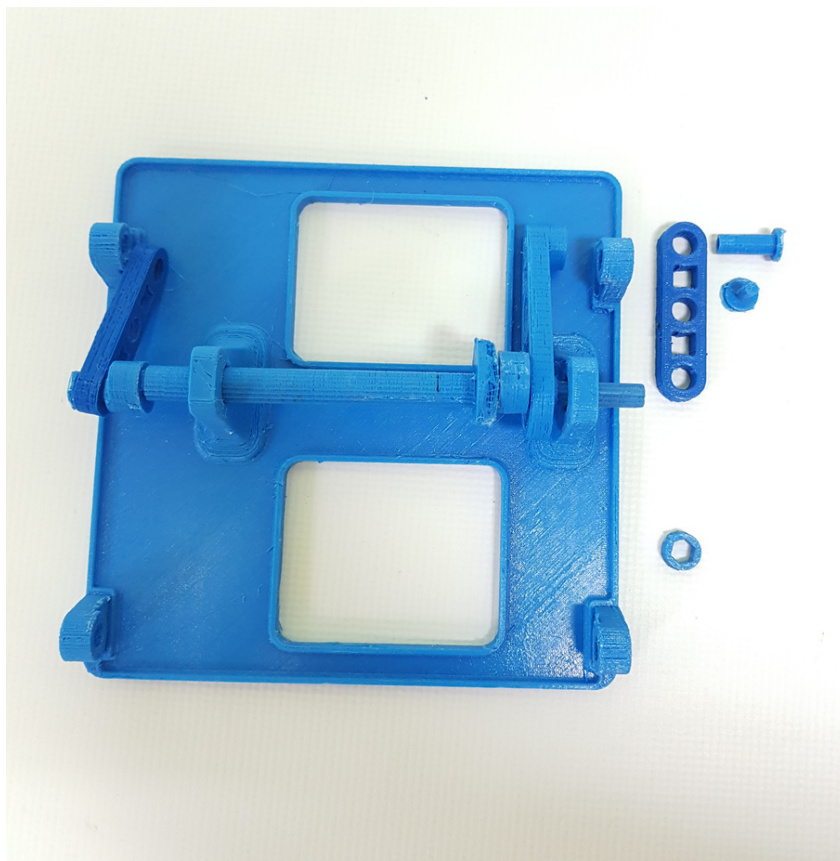
STEP 6: ATTACH THE MEDIUM TRANSMISSION GEAR TO THE AXIS.



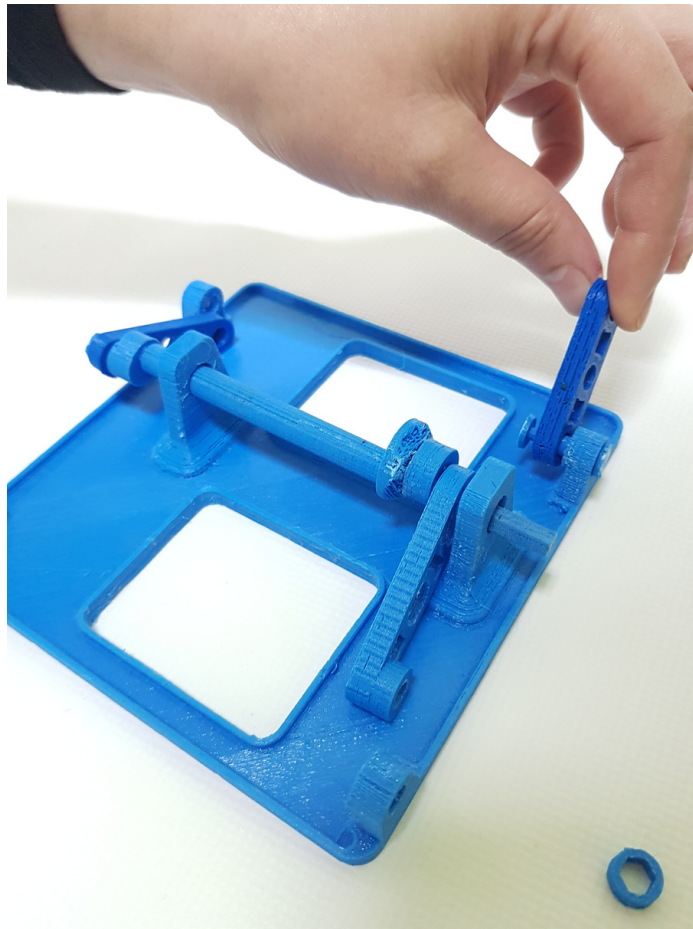
STEP 7: SEAL THE TRANSMISSION GEAR WITH A PIN



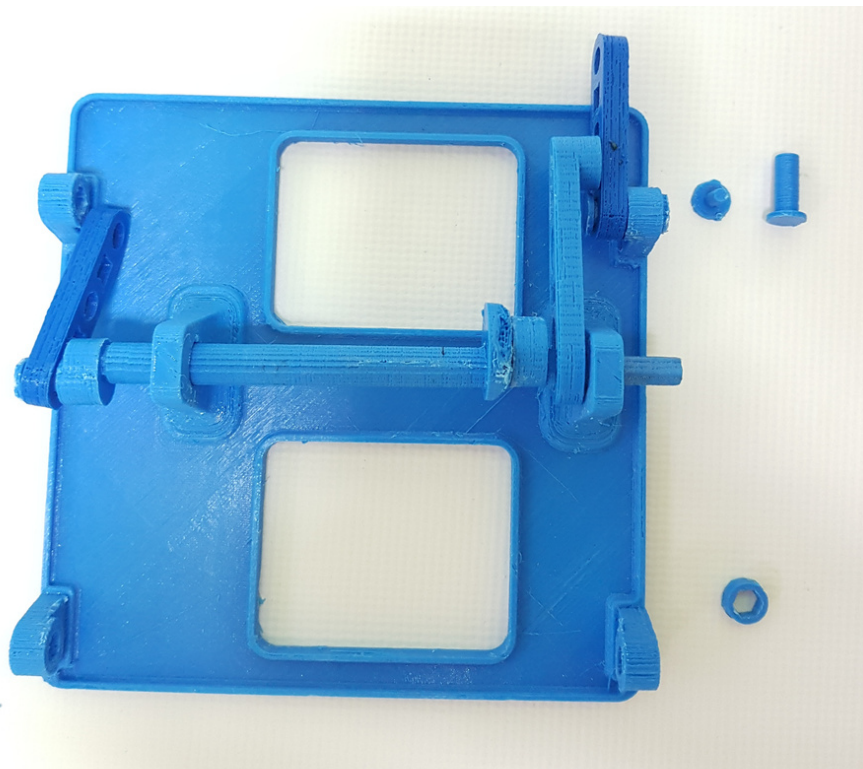
STEP 8: PREPARE A SIMPLE TRANSMISSION GEAR (3), A PIN (5) AND A CAP (6)



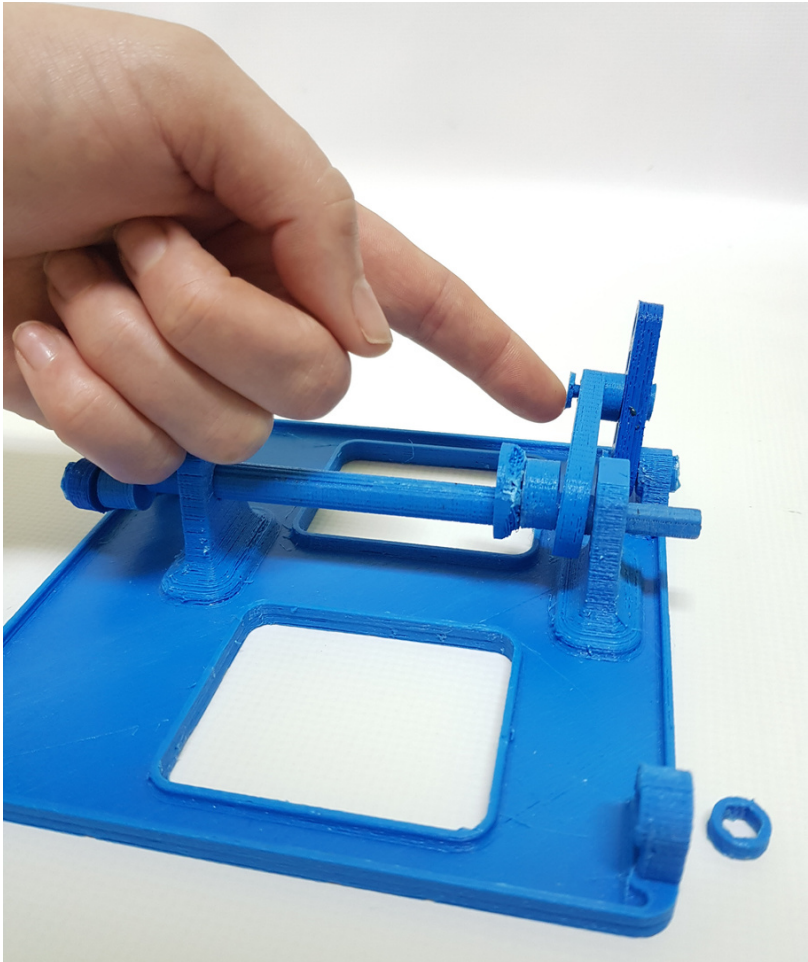
STEP 9: PIN UP THE TRANSMISSION GEAR TO THE TOP RIGHT HOLDER



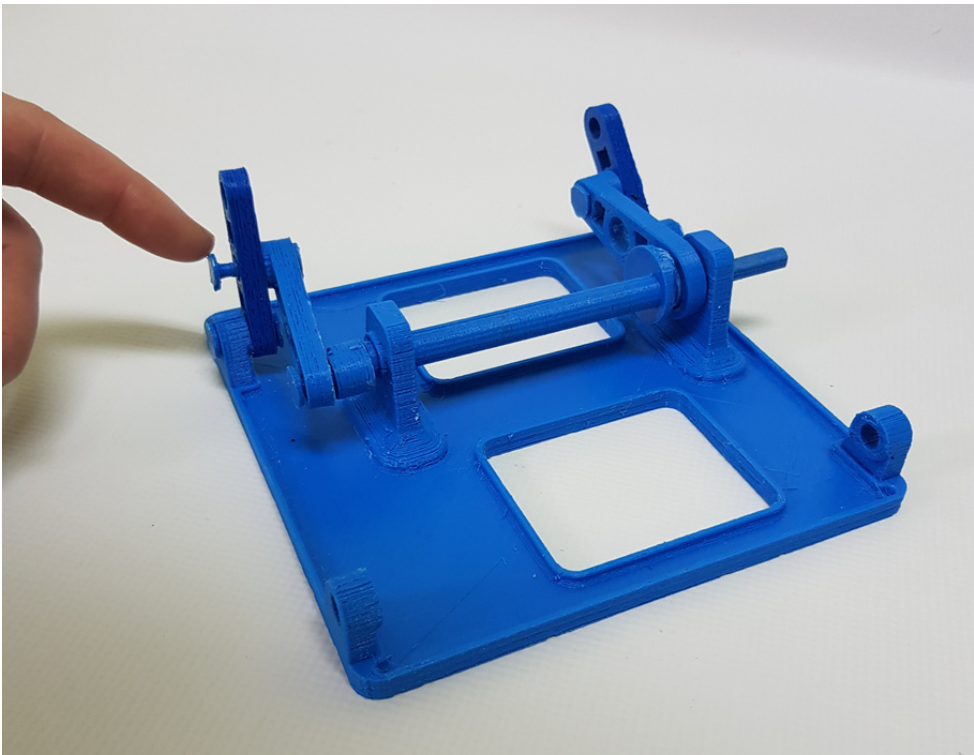
STEP 10: ATTACH THE ECCENTRIC GEAR TO THE TRANSMISSION'S GEAR MIDDLE CAP, PREPARE A PIN (5) AND A CAP (6)



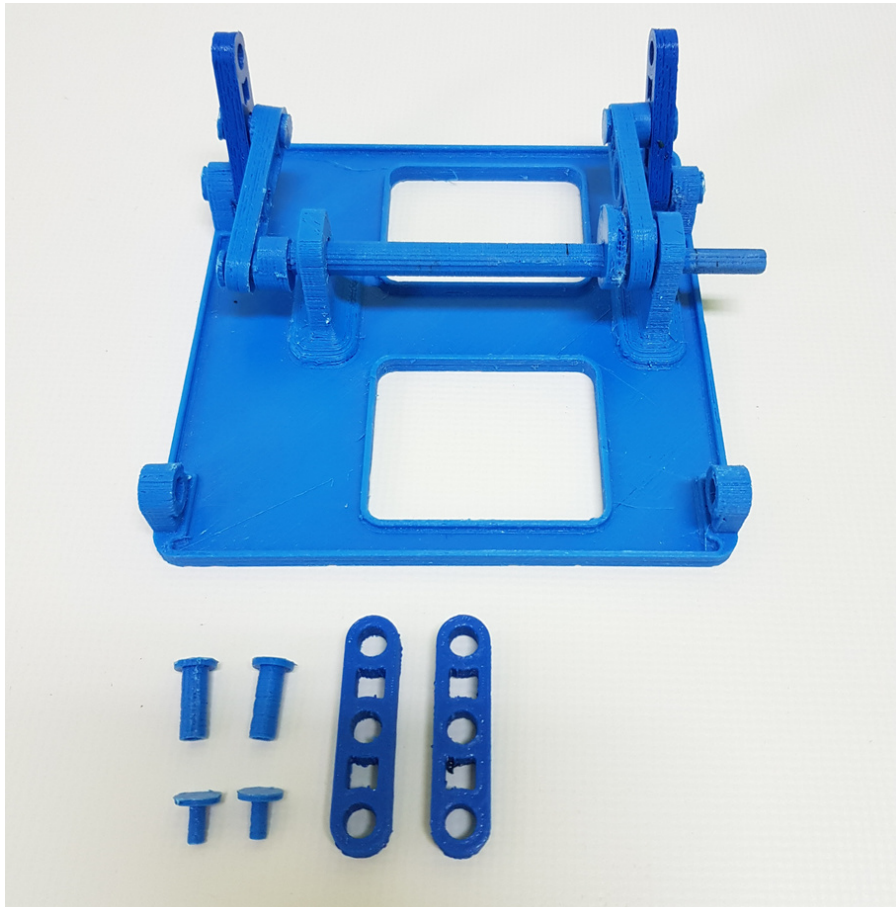
STEP 11: PIN UP THE GEAR



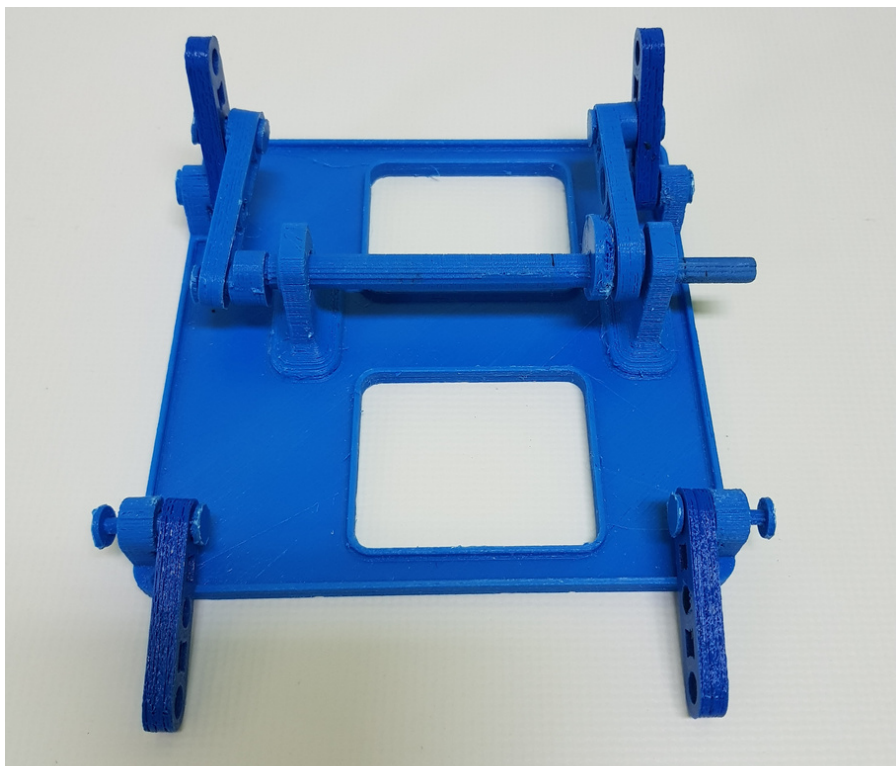
STEP 12: PIN UP THE MEDIUM TRANSMISSION GEAR



STEP 13: PREPARE THE LAST TWO TRANSMISSIONS GEARS, AND TWO SETS OF PINS AND CAPS



STEP 14: PIN UP THE CAPS TO THE TRANSMISSION GEARS



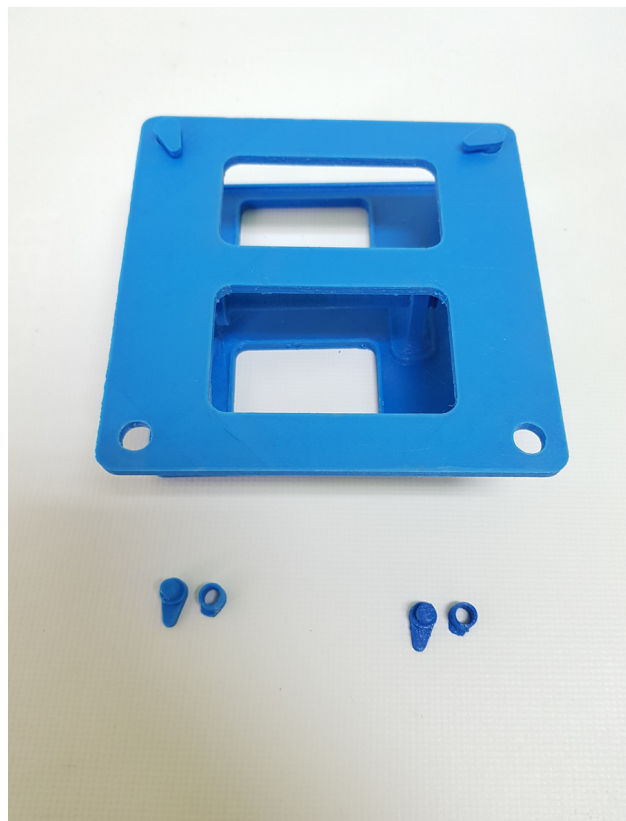
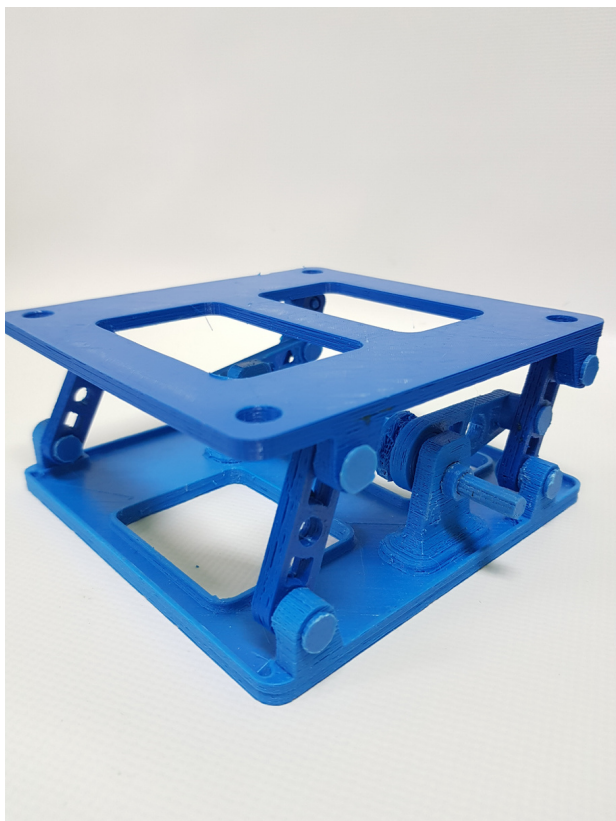
STEP 15: PREPARE THE TOP PLATE (2) AND THE LAST FOUR PINS (5) AND CAPS (6)



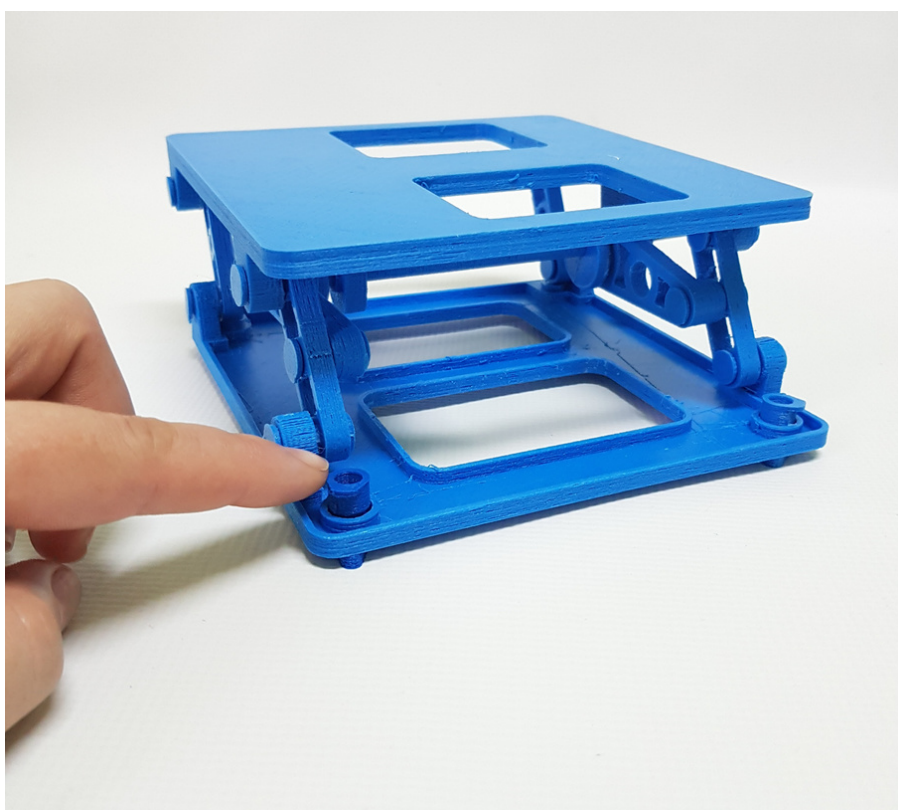
STEP 16: PIN UP THE TOP PLATE.



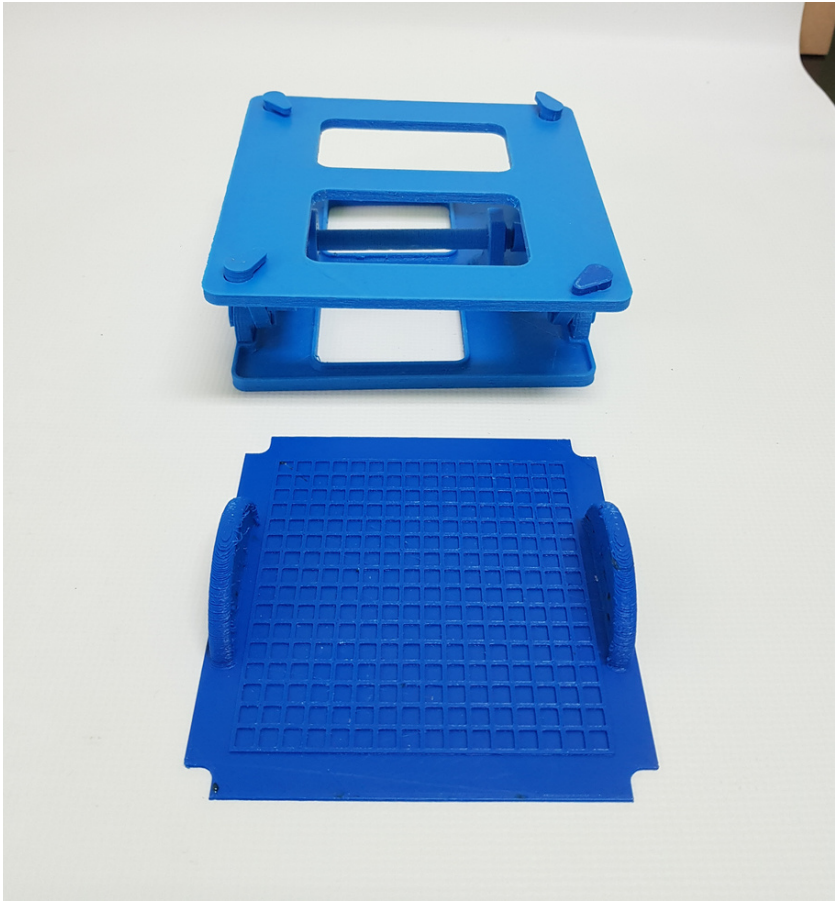
STEP 17: THE BASE AND TOP PLATE ARE ASSEMBLED. PREPARE THE TOP TESTING PLATE (9) AND THE PLATE LOCKS (8)



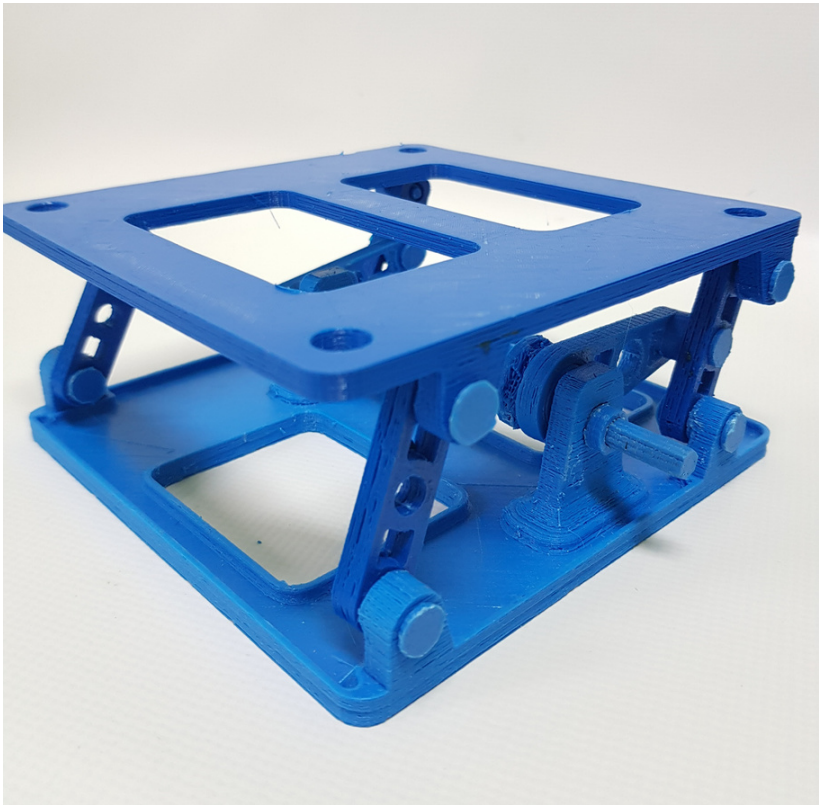
STEP 18: TURN OVER THE SHAKE TABLE, SET UP THE LOCKS AND PUSH THE CAPS



STEP 19: ADJUST THE TOP TESTING PLATE (9)



STEP 20: CONGRATULATIONS! YOU HAVE SUCCESSFULLY PRINTED AND ASSEMBLED A SHAKE TABLE



STAGE 2. BUILD A BETTER WALL



Mainframe:

In this stage of the proposed activity, we aim to enhance students' and teachers' involvement and creative thinking in building a structure, exposing it to a shear wave, observing the effects, searching and implementing solutions, retesting, and debating upon the results.

Connecting various types of creative activities, such as building and enhancing a structure, and practical exercises (shake table) will engage students to learn as active and connected players and engage in possibility thinking, transitioning from what is to what might be. Students and teachers work as a team, take action, have their voices heard, make themselves visible on their terms, and act as agents of change in their lives and beyond.

Understanding the phenomenon

Earthquakes are among the most destructive forces of nature, given by the fact of their violent and unpredictable character. Most of the damages, injuries and even losses of lives are caused by the lack of seismic resilience of buildings.

The first natural question is: Why are buildings collapsing during a strong earthquake? The most basic explanation would be that buildings usually lack resistance to the shear waves and if they are not proper planned and build to withstand for the horizontal component of an earthquake, the bottom levels will eventually concede.



***Collapsed building during the 06.02.2016 earthquake in Taiwan, Mw 6.4
Source: <https://www.wsj.com/articles/taiwan-officials-launch-rescues-1454816862>***

Can we improve a building to the earthquake resilient?

Following the **first seven steps**, we will build a structure only with horizontal and vertical elements and test it on the shake table to observe the lack of resistance against shear waves.

Following **steps 8 to 10**, we will improve the building with different structural elements, test it after each upgrade and observe the outcome.



Necessary materials:

1. Wooden pallet – 10 pcs
2. Wooden base – 9 cm x 16 cm
3. Screws M6 – 8 pcs
4. Butterfly screw cap – 6 pcs
5. Screw rove – 2 pcs
6. Screwdriver machine
7. Paper clips – 8 pcs
8. Paper sheet – 11 cm x 15 cm
9. Paper strips – 2 pcs, 1,5 cm x 18 cm
10. Rubber bands – 2 pcs



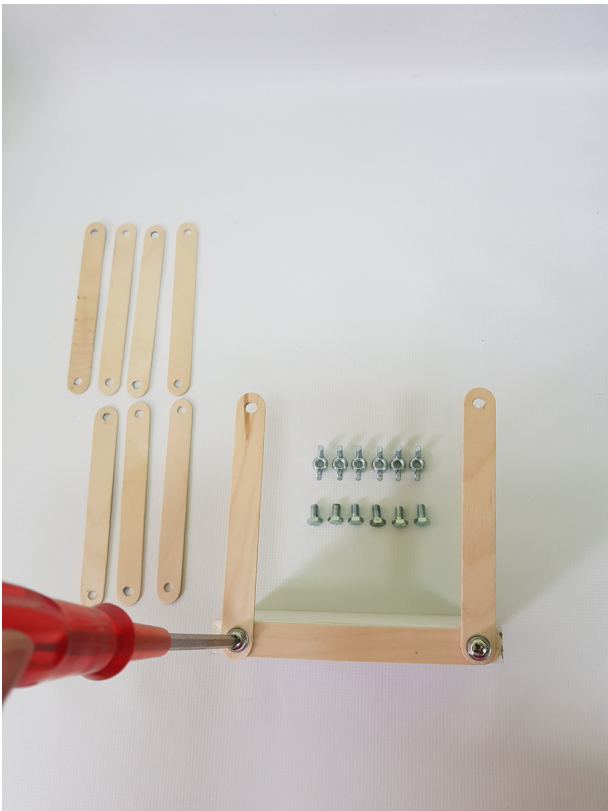
STEP 1: MARK YOUR DRILLING POINT ON THE WOODEN PALLET



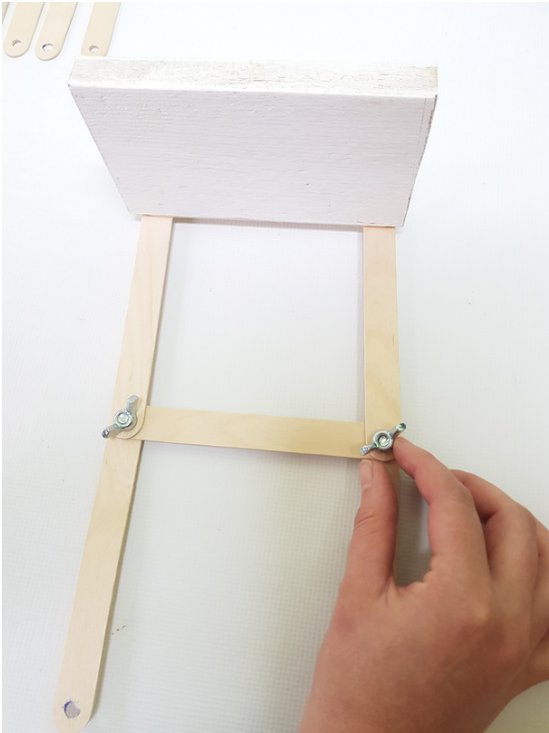
STEP 2: DRILL HOLES TO ALL THE WOODEN PALLETS



STEP 3: START ASSEMBLING THE STRUCTURE. FIX THE BASE ON THE WOODEN BOARD USING TWO SCREWS AND SCREW ROVES.



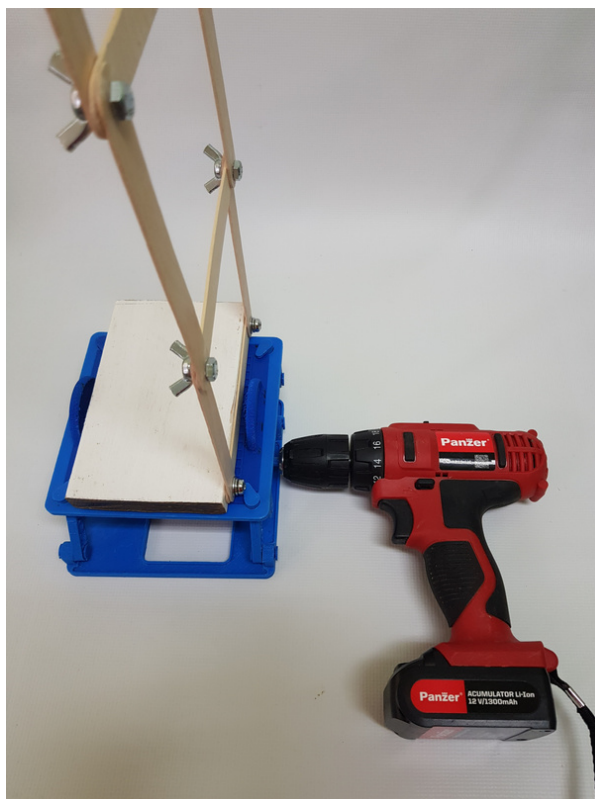
STEP 4: CONTINUE TO ASSEMBLE THE WOODEN PALLETS USING THE REST OF THE SCREWS AND BUTTERFLY CAPS.



STEP 5: PLACE THE STRUCTURE ON THE SHAKE TABLE USING STICKY PASTE OR A GLUE GUN. PREPARE TO CONNECT THE SCREWDRIVER MACHINE TO THE MAIN AXIS OF THE SHAKE TABLE.



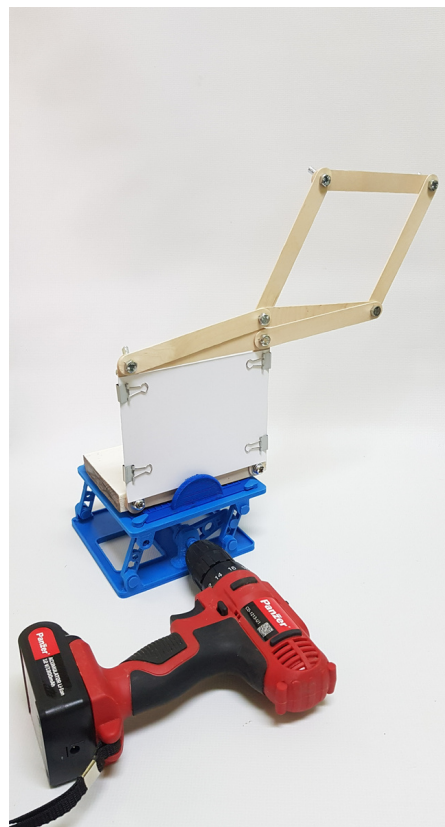
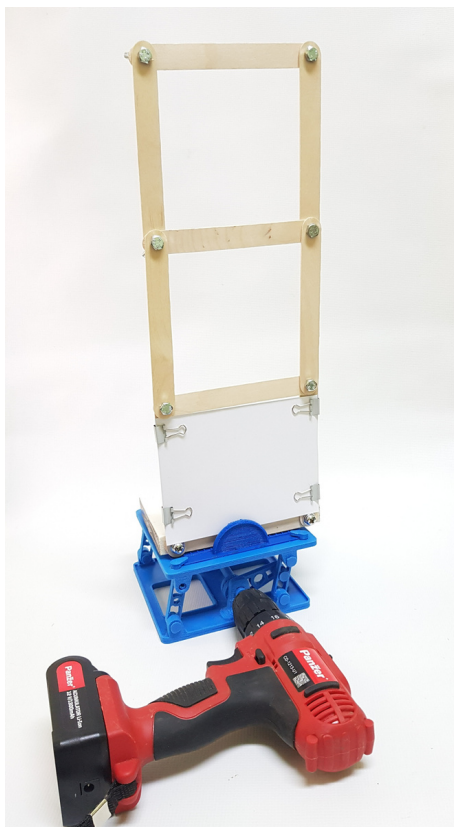
STEP 6: CONNECT THE SCREWDRIVER MACHINE TO THE AXIS OF THE SHAKE TABLE AND MAKE THE FIRST TEST.



STEP 7: OBSERVE THE EFFECTS: THE STRUCTURE COLLAPSED IMMEDIATELY BECAUSE IT DOES NOT HAVE SHEAR RESISTANCE



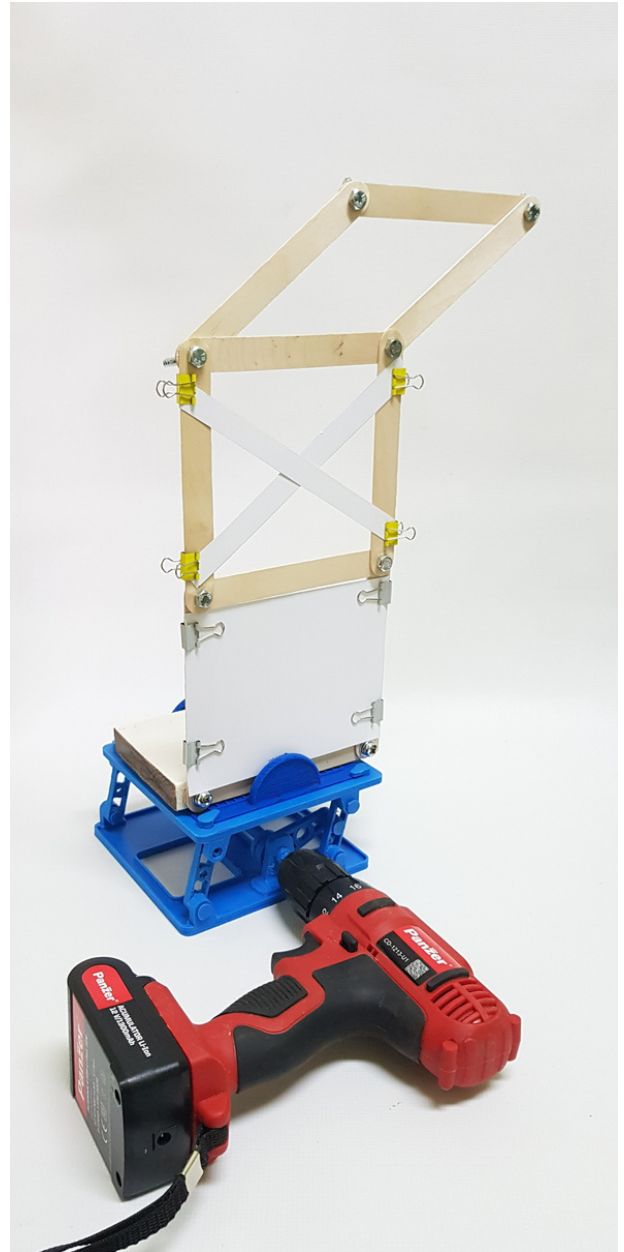
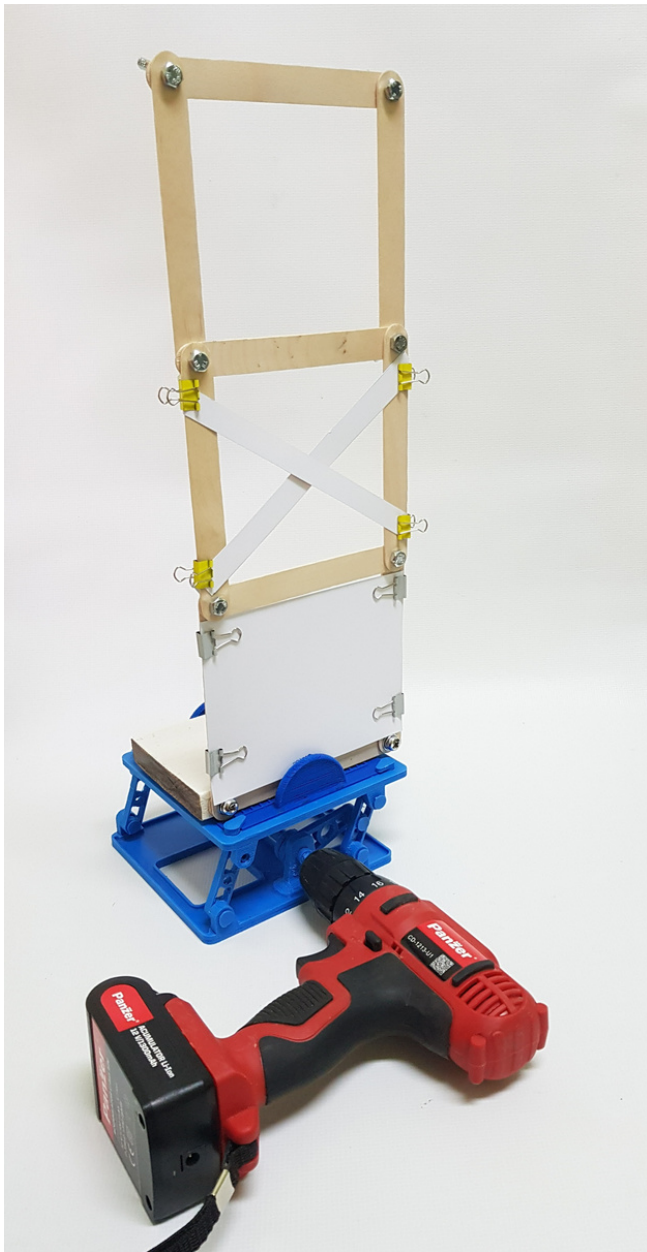
STEP 8: NOW WE MUST FIND SOLUTIONS TO PUT SHEAR STRENGTH IN THE BUILDING. ONE WAY TO DO THIS IS TO INSERT SHEAR WALLS. WE CAN RESEMBLE A SHEAR WALL BY PLACING A PAPER SHEET WITH CLIPS ON THE BOTTOM STORY. NOW TEST THE STRUCTURE AND OBSERVE HOW THE BOTTOM STORY WITHSTANDS THE EARTHQUAKE AS THE UPPER STORIES COLLAPSE.



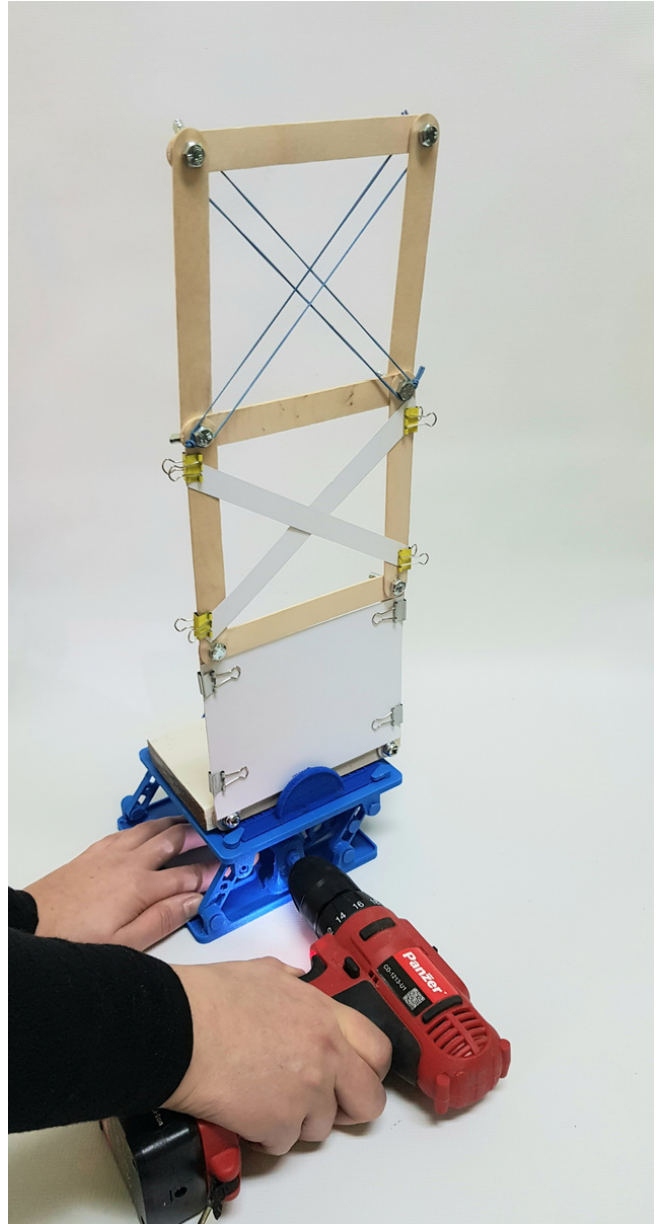
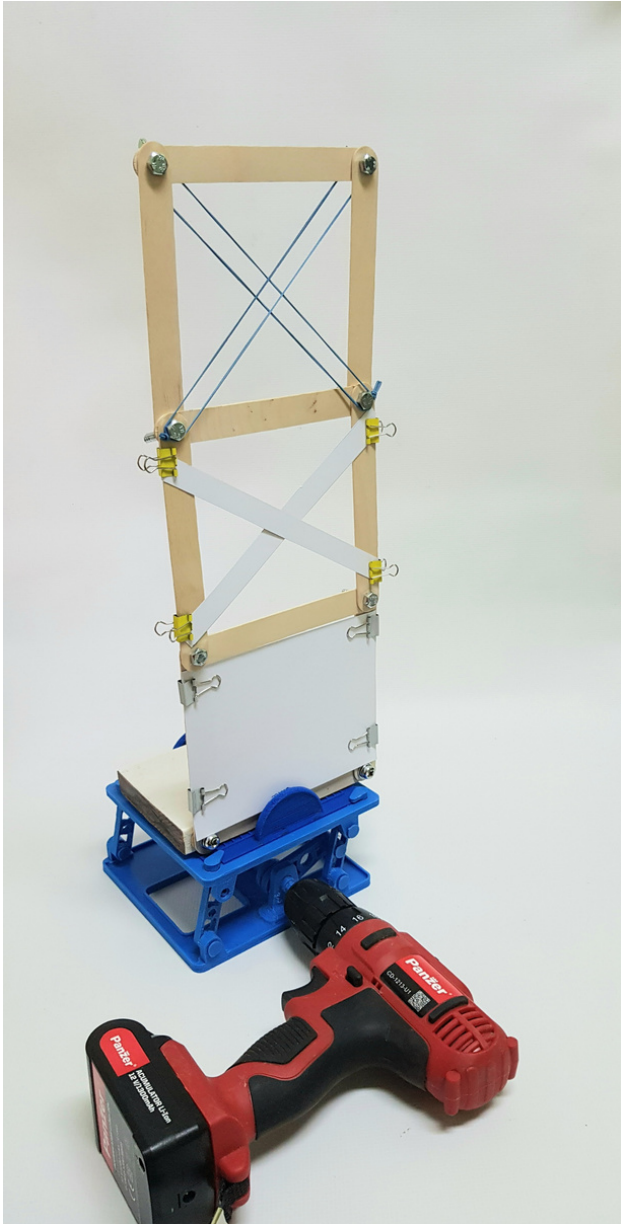
STEP 9: TO CONTINUE ENHANCING THE STRUCTURE, WE CAN ADD DIAGONAL STRIPS TO THE SECOND LEVEL.

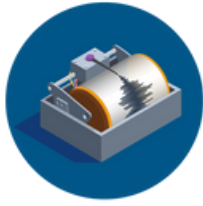
OBSERVE HOW THE PAPER STRIPS DO NOT HAVE COMPRESSIONAL STRENGTH (CHARACTERISTIC TO THE PRIMARY WAVES), BUT DO HAVE A HIGHER TENSILE STRENGTH THAT IS MOSTLY NEEDED IN THE CASE OF SHEAR WAVES (CHARACTERISTIC TO SECONDARY WAVES).

PLACE THE PAPER STRIPS ON THE DIAGONAL USING THE CLIPS. TEST THE STRUCTURE AND OBSERVE HOW BOTH THE BOTTOM AND THE FIRST LEVEL ARE NOW SHEAR RESISTANT.



STEP 10: TO SECURE THE TOP STORY, ADD THE RUBBER BAND, ALSO DIAGONALLY TO PROVIDE SHEAR STRENGTH FROM BOTH DIRECTIONS. YOU CAN ALSO TRY WITH A NON-ELASTIC STRING. KEEP IN MIND THAT THE RUBBER BAND AND STRING DO NOT HAVE AT ALL COMPRESSIONAL STRENGTH BUT OFFER A FULL SHEAR RESISTANCE PROTECTION. TEST AND OBSERVE HOW THE WHOLE BUILDING IS NOW SHEAR RESISTANT BY ADDING ONLY A FEW AND SIMPLE STRUCTURAL ELEMENTS.





SEISMO-LAB

Annex 3 - Instructions, instruments, and materials for How to estimate the magnitude of seismic shocks by comparison



INTRODUCTION

The local seismic magnitude (ML) is a dimensionless quantity even if its calculation is based on the numerical entity of the ground displacement at a given distance from the epicenter. Although the seismic data (waveforms) that students could acquire from both the research networks and/or the educational network of the SEISMO-Lab project do not directly provide the physical measurement of ground displacement, these data can be used to estimate the local magnitudes of seismic shocks comparing them to a reference shock of known magnitude.

This activity is aimed at high school students (16-18 years old) and aims to familiarize the participants with this peculiar concept.

The local Magnitude (ML) as conceived by the American physicist Charles Richter in 1935 is expressed by the formula:

$$ML = \log A$$

A is the amplitude of the maximum horizontal displacement of the ground measured 100 km from the epicentre of an earthquake recorded by a standard-type seismograph (Wood- Anderson). Considering that the amplitude value should be expressed in micrometers (μm), a Magnitude 3 earthquake would imply a maximum ground displacement of $10^3 = 1.000 \mu\text{m}$ (1 mm) 100 km from the epicenter. A Magnitude 5 event would cause a displacement of $10^5 = 10.000 \mu\text{m}$ (10 cm) at the same distance.



Considering that not always standard type seismograph is available exactly 100 km far from an occurring earthquake, Richter proposed **different formulas** aimed at correcting the differences due to both the variations in distance between the epicenter and the seismograph and the geological features of the territory. In particular, Richter proposed two different formulas to calculate the local Magnitude in California, respectively:

$$ML = \log A + 1,6 \cdot \log D - 0,15 \text{ for earthquakes recorded less than 200 km from the epicentre.}$$

and

$$ML = \log A + 3 \cdot \log D - 3,38 \text{ for earthquakes recorded between 200 and 600 km far}$$

where in both cases D represents a corrective factor relating to the epicentral distance.

1. In reality these displacement values are theoretical and would be revealed by the standard Wood-Anderson seismograph given its technical characteristics (amplification factor and resonance period). In any case, the proportionality relationship between the magnitude of different earthquakes remains valid, at least below magnitude values of 7.

Since the numerical value of the Magnitude is a decimal logarithm, this means that a difference of one degree on the Richter scale implies a variation of the displacement of the ground by a factor of 10 and that even a difference of one-tenth of a degree is quite significant in terms of displacement (see picture below)

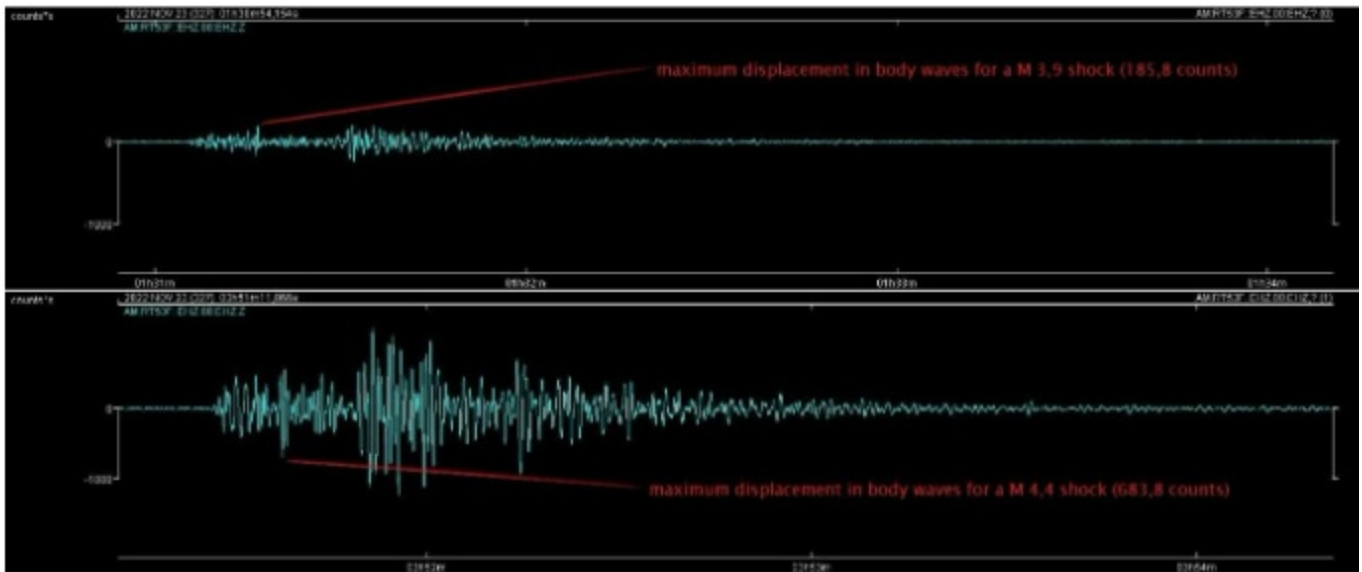


Fig. 2: the waveforms related to two different seismic shocks but recorded by the same seismometer at the same epicentral distance. In this case, a Magnitude 3.9 shock (above) causes a maximum displacement for body waves of 185,8 counts, while a Magnitude 4.4 (below) a displacement of 683,8 counts.



The waveforms of real earthquakes occurring on Earth's surface are available for everybody on the web interface of the EIDA platform, similarly, the events occurring in the Mediterranean area can be acquired from the [SEISMO-Lab project seismic network](https://snac.gein.noa.gr/project-network) <https://snac.gein.noa.gr/project-network>

In both cases, the so-gathered data don't report the physical value of the ground displacement (neither of the ground motion velocity nor acceleration) because these values depend on the single sensors' technical features and their digitizers. Indeed, the values on the Y axes in the waveforms gathered from these platforms are expressed as "counts," a quantity with an exquisitely technical-computer meaning that would allow us to trace the biological value of the displacement only through some information that we do not have.

Anyway, we can get around the problems due both to the fact that the amplitudes are expressed as "counts" and to the fact that we do not always have a seismometer placed precisely 100 km from the epicenter, starting from the assumption that for magnitudes lower than seven and at a distance lower than 600 km, the relationship between maximum amplitude and local Magnitude for different earthquakes remains proportional.

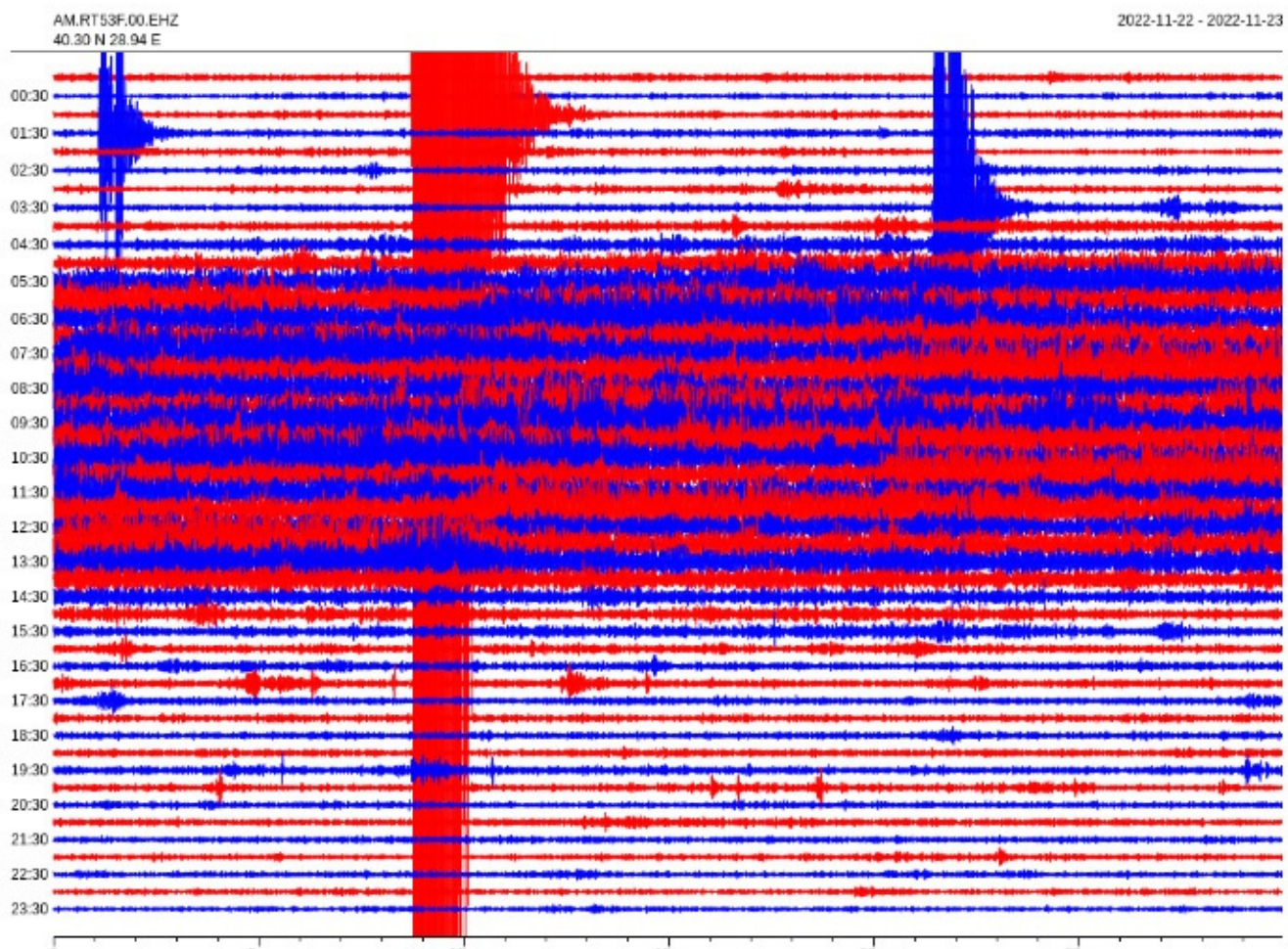
Similarly, to estimate the local Magnitude of a seismic shock, we should use the horizontal displacement of the ground. At the same time, the SEISMO-Lab network is equipped just with vertical sensors. These problems can also be bypassed, considering that the ratio between vertical and horizontal displacement remains proportional in a specific range of epicentral distances and Magnitudes. Therefore, we will compare Magnitudes, starting from a referring Magnitude rigorously calculated by a research center.

However, these data could be effectively exploited to let high school pupils better understand the meaning of the peculiar concept of local Magnitude. To be effectively carried out in a class, the involved pupils should be quite skilled in math and in particular they should be quite familiar with the concept of decimal logarithm. The ideal audience of such a kind of experience would be pupils of the last years of high school (11th-13th degree).

As already said in the introduction, even if the physical values on the Y axes are lacking we can exploit more waveforms related to different seismic shocks if they are generated from the same source and recorded by the same seismometer.

Example 1. The seismic sequence of November 23rd, 2022 in Golyaka-Duzce, Turkey

As first example, we can start observing the daily seismic activity as felt by the station RT53F installed in Bursa (TR) on November 23rd, 2022.



The waveforms of the different earthquakes started respectively at 1:08, 1:31, and 3:51 UTC are visible in the image. We don't know the physical values of their amplitudes, but it's clear that the one at 1:08 shows the largest amplitudes, followed by the one at 3:51, while the one at 1:31 is the lightest. This seismic sequence seems to provide good staff for our experiment.

STEP 1: DETERMINING THE MAGNITUDE

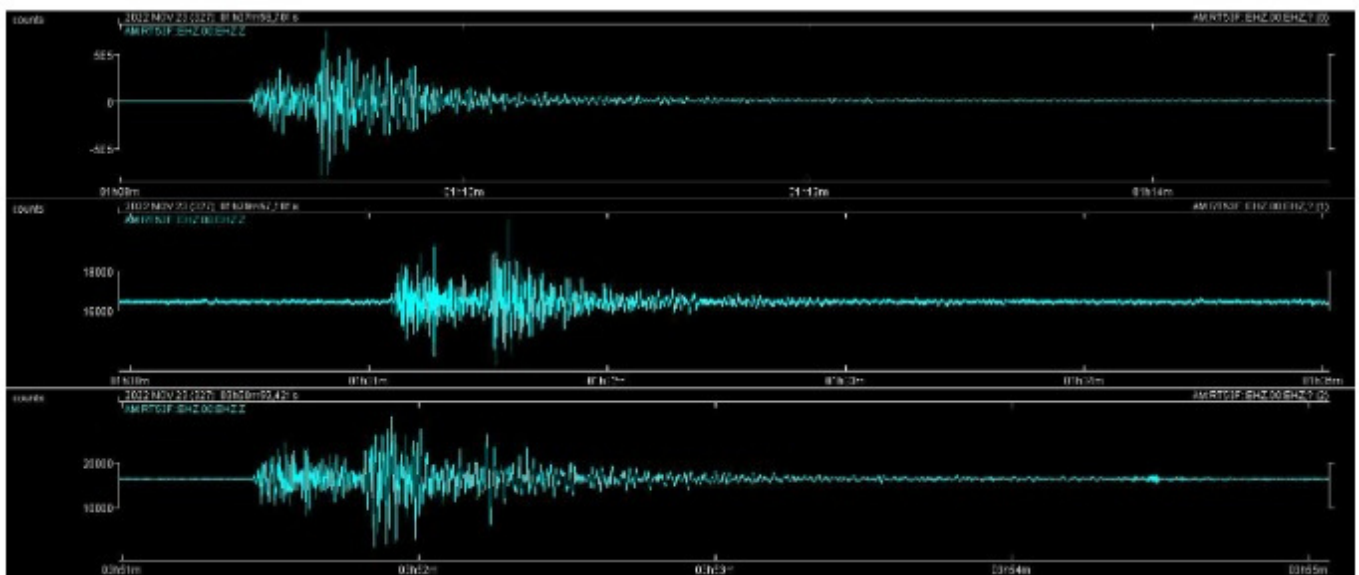


As first step we can determine the Magnitude of just the first and strongest of these three shocks consulting the seismic database of Boğaziçi University of Istanbul - <http://www.koeri.boun.edu.tr/sismo/2/latest-earthquakes/automatic-solutions/> for the event of 1:08 is reported local Magnitude (ML) 6,2.

All the shocks we can observe on the helicorder occurred in north-western Turkey ($40,79^{\circ}$ N; $30,95^{\circ}$ E) about 178 km far from the seismic station RT53F ($40,299^{\circ}$ N; $28,944^{\circ}$ E) of the SEISMO-Lab educational network. The picture below shows the waveforms of the three main shocks in miniseed numerical format gathered from the SEISMO-Lab network as can be observed using the software SeisGram2K.

STEP 2 : THEN DOWNLOAD THE WAVEFORMS OF THE THREE SHOCKS IN NUMERICAL FORMAT.

The picture below shows the waveforms of the three main shocks in miniseed numerical format gathered from the SEISMO-Lab network as can be observed using the software SeisGram2K.

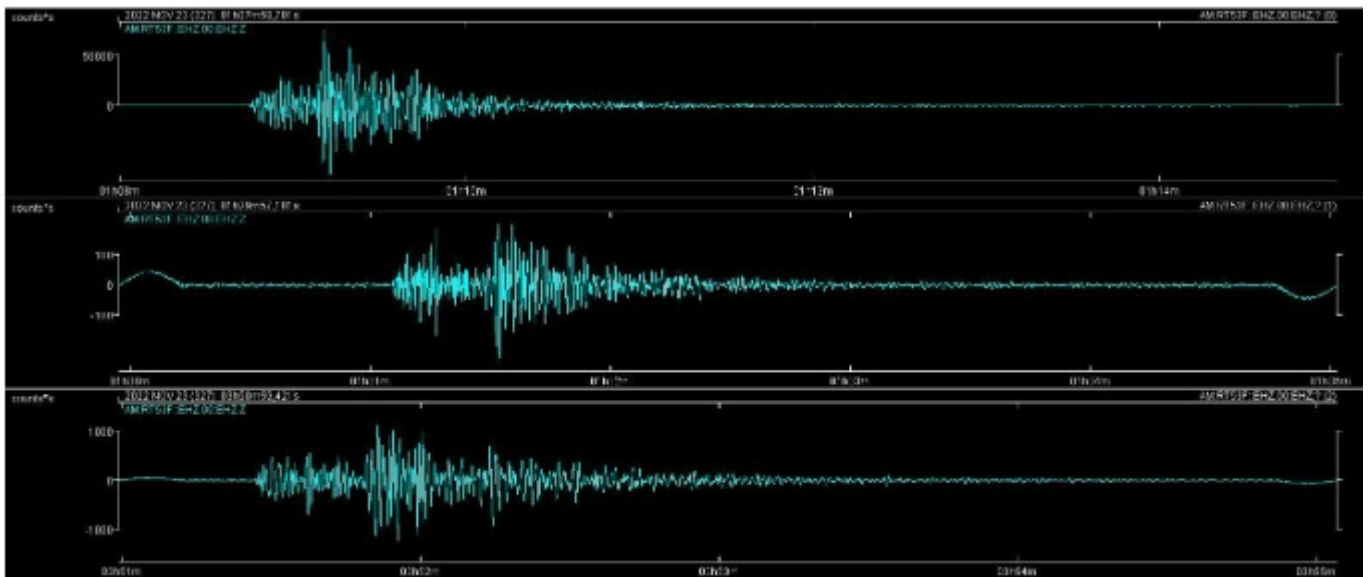


Even if the amplitudes of the three waveforms seem similar, reading the values on the Y axes, we can verify that they enormously vary. Therefore, we should remind that the raw waveforms, as downloaded from the network database, express the motion velocity of the displacement of the ground, but to get something related to just the displacements, SeisGram2K allows us to integrate the waveforms.

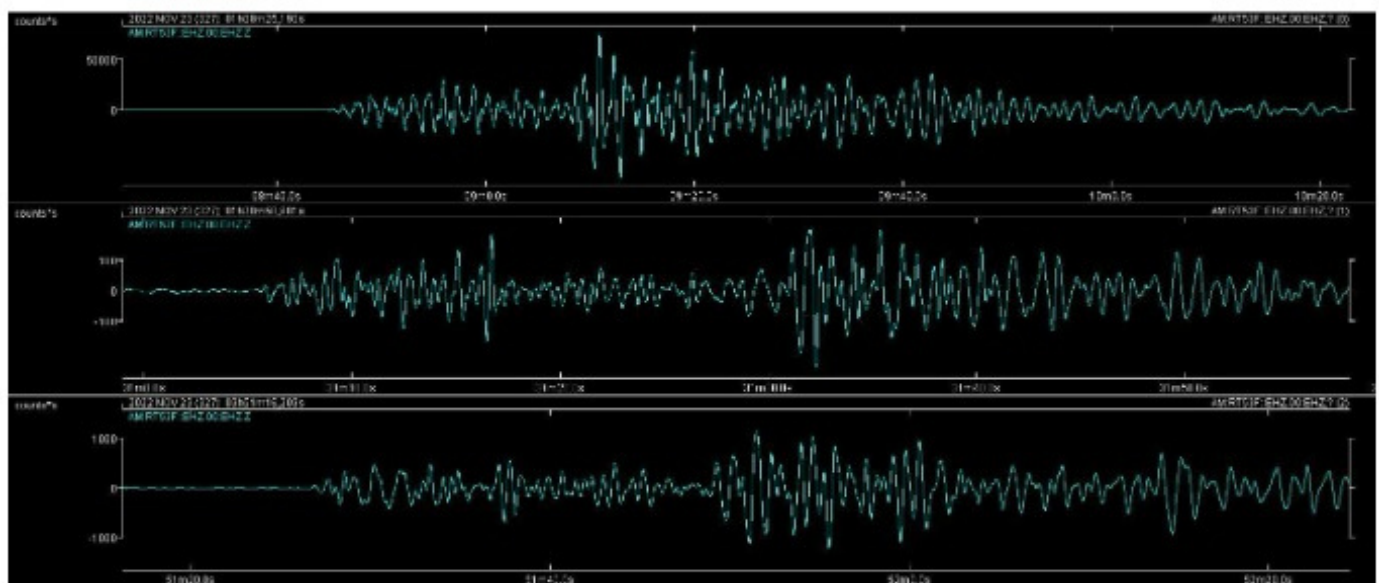
SeisGram2K can be downloaded for free here: http://alomax.free.fr/seisgram/ver70/SeisGram2K_install.html. We advise you to install the .jar version on your PC or PCs at your school because this is a batch type file that works like software but does not need to be installed, thus avoiding all the problems caused by the firewall of a public network, etc. To make it work, you just need to have Java installed on your PC as well.

STEP 3: INTEGRATE THE THREE WAVEFORMS AFTER WE WILL HAVE FILTERED THEM PRESERVING JUST THE FREQUENCIES BETWEEN 3,0 HZ AND 5,0 HZ

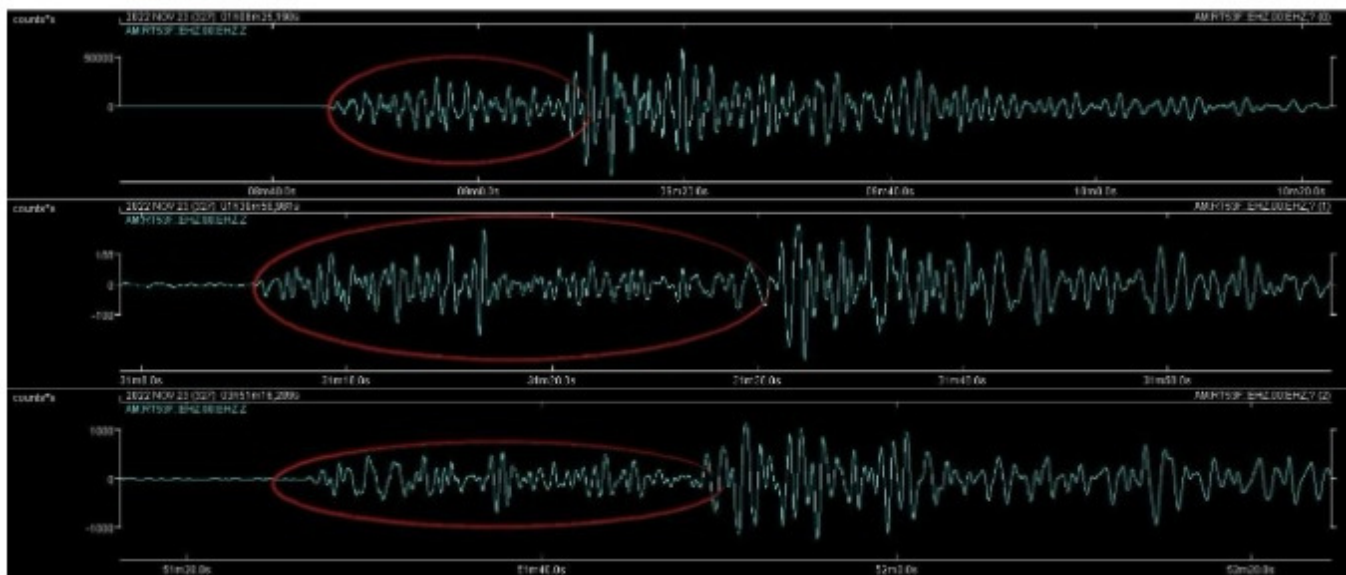
So, we have to integrate the three waveforms after filtering them, preserving just the frequencies between 3,0 Hz and 5,0 Hz to eliminate the noise and the long-period waves that could affect the correct visualization of the ground displacements. The results are shown in the picture below:



STEP 4: FINALLY, THE SOFTWARE ALLOWS ALSO TO STRETCH THE WAVEFORM TO BETTER VISUALIZE THE DIFFERENT PHASES.

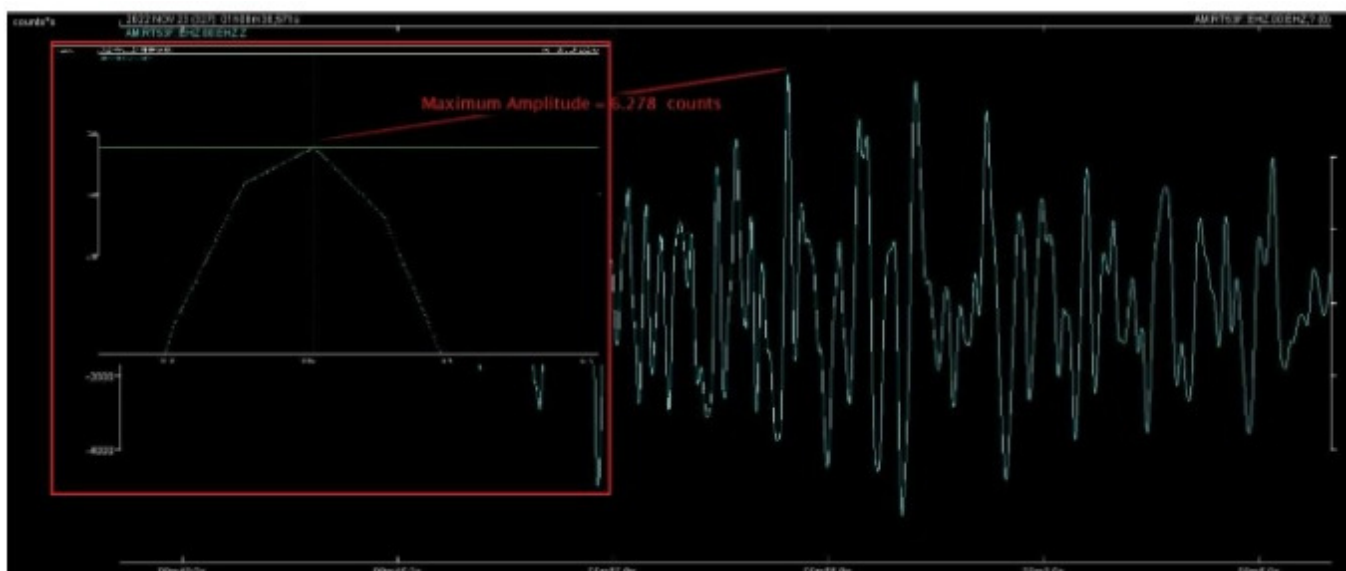


The local Magnitude is estimated starting from the maximum amplitudes of the body waves (P and S, the fastest) characterizing the first parts of the waveforms and highlighted by the red ellipses in the picture below:



STEP 5 : OPEN MORE DETAILS ON A PARTICULAR POINT OF THE WAVEFORM.

SeisGram2K also has a function that allows you to open more details on a particular point of the waveform. In this case we use it to examine the maximum amplitude peaks in detail and measure their value. The picture below shows the peak of maximum amplitude and its value for the shock of known magnitude (6.278 counts).



STEP 6: GATHERED VALUES

Once we will have elaborated the three waveforms and measured their maximum displacements of body waves, the gathered values will be:

Event	Max. displacement in counts (D)	Corresponding theoretical physical displacement (A)	Local Magnitude (M_L)
n.1: (1:08 UCT)	29.862	1.584.893 μm	6,2
n.2: (1:31 UCT)	186	?	unknown
n.3: (3:52 UCT)	683	?	unknown

As already said, the local Magnitude of the first event is reported in the database of the Boğaziçi University of Istanbul, and we will use it as a referring value.

Magnitude 6,2 means a theoretical displacement of the ground of 1.584.893 μm (1,58 meters! But it is just a theoretical value) whose maximum displacement on the waveform corresponds to 29.826 counts.

If the proportional relationship between the maximum displacements of the different waveforms and the magnitudes is valid, then we have that:

$$D1 : A1 = D2 : A2$$

Where **D1** is the maximum displacement of the body waves measured on the waveform related to the Magnitude 6,2 earthquake that occurred at 1:08, **A1** is the corresponding theoretical amplitude of ground displacement, **D2** is the maximum displacement measured on the waveform related to the earthquake that occurred at 1:31 and **A2** is its corresponding theoretical amplitude of ground displacement that is unknown, but which can be calculated with a simple proportion:

$$29.826 \text{ counts} : 1.584.893 \mu\text{m} = 186 \text{ counts} : A2$$

$$A2 = (1.584.893 * 186) / 29.826 = 9.871,75 \mu\text{m}$$

$$ML2 = \log_{10} 9.871,75 = 3,99$$

Of course, we can apply the same proportion to the earthquake that occurred at 3:51 (683 counts):

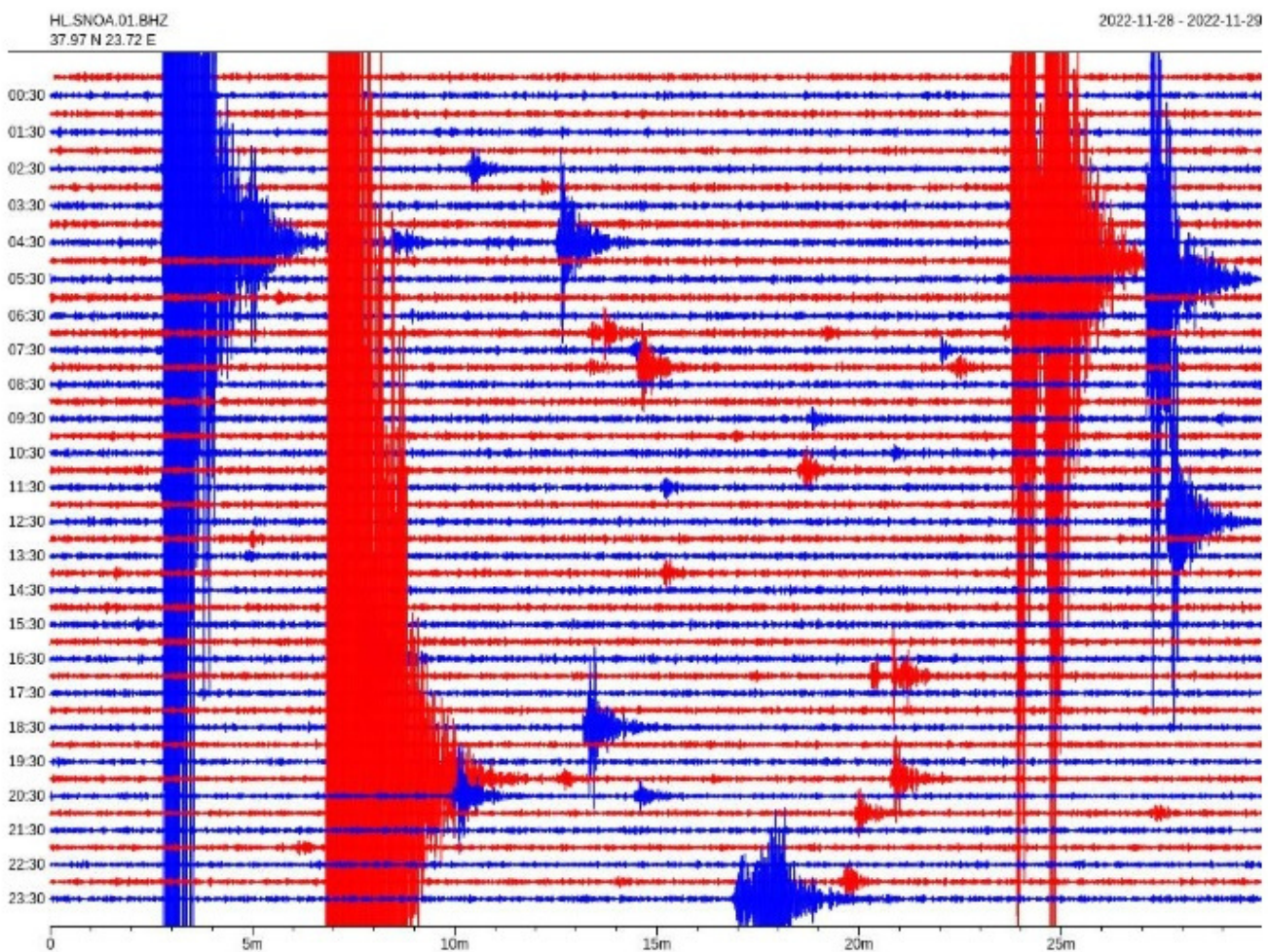
$$A3 = (1.584.893 * 683) / 29.826 = 36.249,48 \mu\text{m}$$

$$ML2 = \log_{10} 36.249,48 = 4,56$$

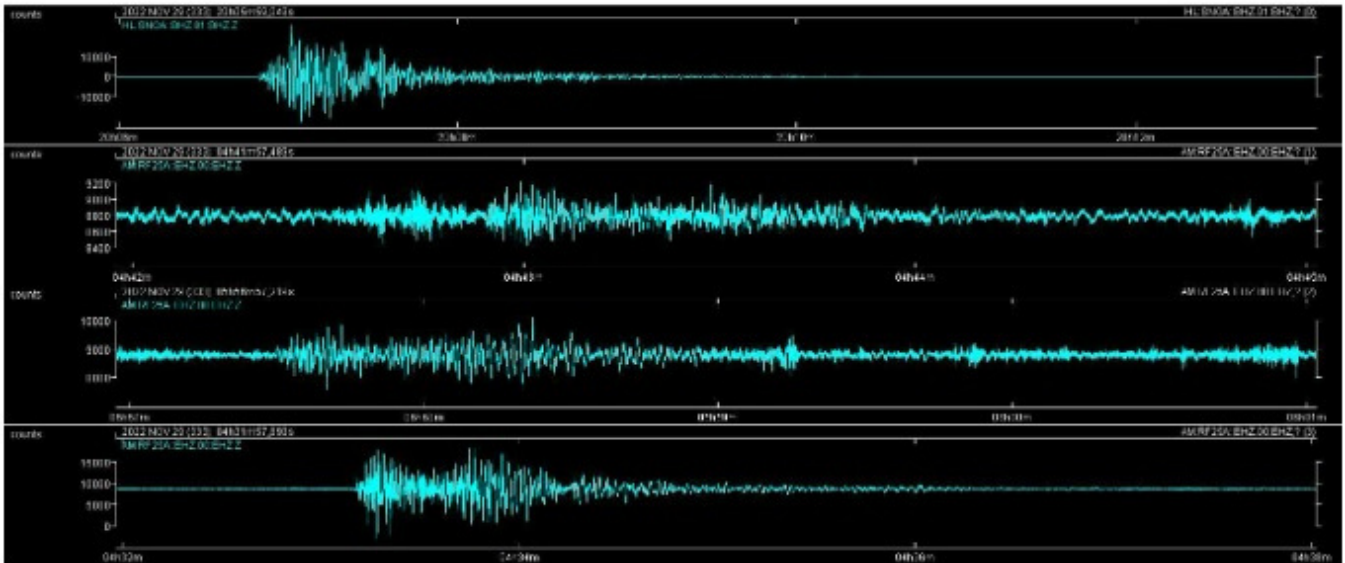
As feedback, we can consult again the earthquake database of Boğaziçi University of Istanbul that reports respectively ML 4,0 for the event of 1:31 and 4,6 for the one of 3:51.

Example 2. The seismic sequence of November 29th, 2022 in Euboea, Greece.

The helicorder of the seismic activity recorded by the SNOA seismometer on November 29, 2022 shows several rather strong tremors that occurred not very far from the seismic station which is installed right in the centre of the Athens.



Following the procedure for downloading the data in digital format from the SEISMO-Lab platform, we obtained the waveforms relating to the tremors that occurred respectively at 4:32, 4:42, 5:57 and 20:06.



STEP 1: VALUE OF THE LOCAL MAGNITUDE OF AT LEAST 1 AFTERSHOCK

As in the previous example, we need the value of the local magnitude of at least one of the aftershocks to determine those of the others by comparison. For this proposal, we are going to consult the database of the National Observatory of Athens, where the station from which we obtained the waveforms is installed:

<http://bbnet.gein.noa.gr/HL/seismicity/catalogues/real-time-catalogue>

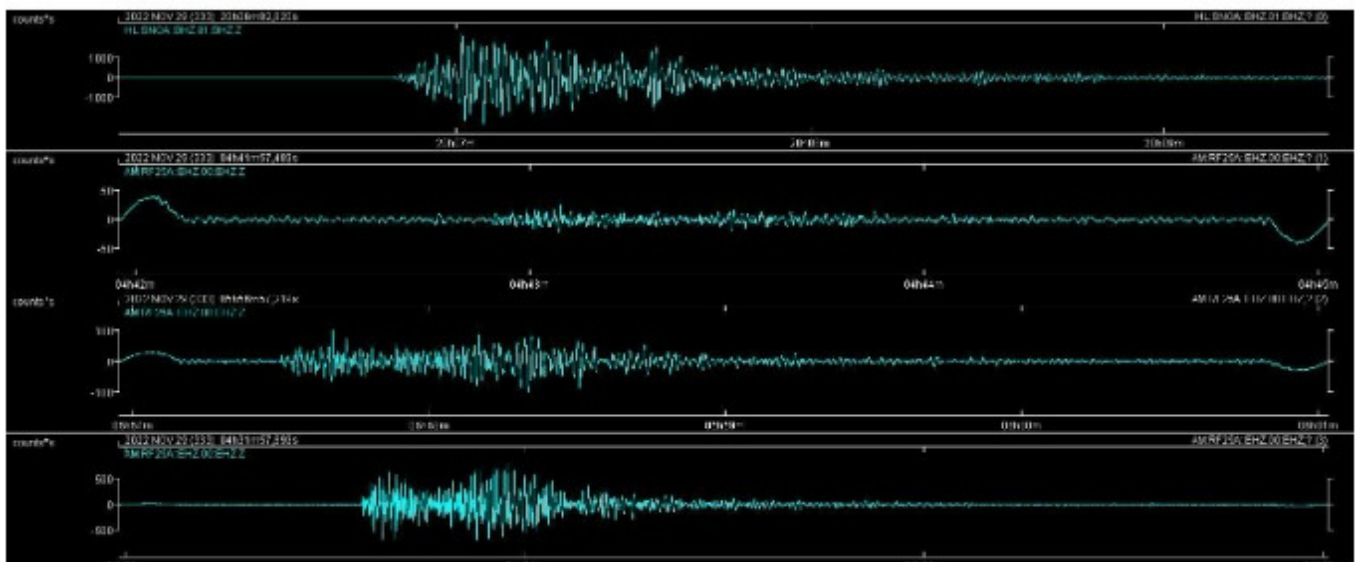


In particular, we can verify the magnitude of the event that from the helicorder seems to be the strongest, the one occurred at 20:06 is 5,0.

Source: http://bbnet.gein.noa.gr/Events/2022/11/nea2022xkgfp_info.html

STEP 2: FILTER AND INTEGRATE THE WAVEFORMS

In the meantime, we also can filter (range 1,0 - 3,0 Hz) and integrate the waveforms - picture below:



STEP 3: MEASURE THE MAXIMUM DISPLACEMENTS OF BODY WAVES FOR EACH WAVEFORM

Then we measure the maximum displacements of body waves for each waveform and report them in the table below:

Event	Magnitude from NOA	Counts	Theoretical displacement	Found displacement	Magnitude for comparison
n.1 (20:06 UTC)	5,0	1248	100.000 μm	#RIF!	#RIF!
n. 2 (4:32 UTC)	?	673,00	?	53.926,28 μm	4,7
n. 3 (4:42 UTC)	?	25,00	?	2.003,21 μm	3,3
n. 4 (5:57 UTC)	?	99,00	?	7.932,69 μm	3,9

In the last column of the table are also reported the unknown Magnitudes estimated by comparison. Consulting the earthquakes database of the National Observatory of Athens, we can find $ML=4,7$ for the event of 4:32, $ML=3,2$ for the one of 4:42, and $ML=3,9$, respectively, for the one of 5:57.

Although, in a couple of cases, there is a difference of a tenth of a degree between the magnitudes estimated by comparison and those provided by the NOA database, the proximity of the results confirms the method's effectiveness.

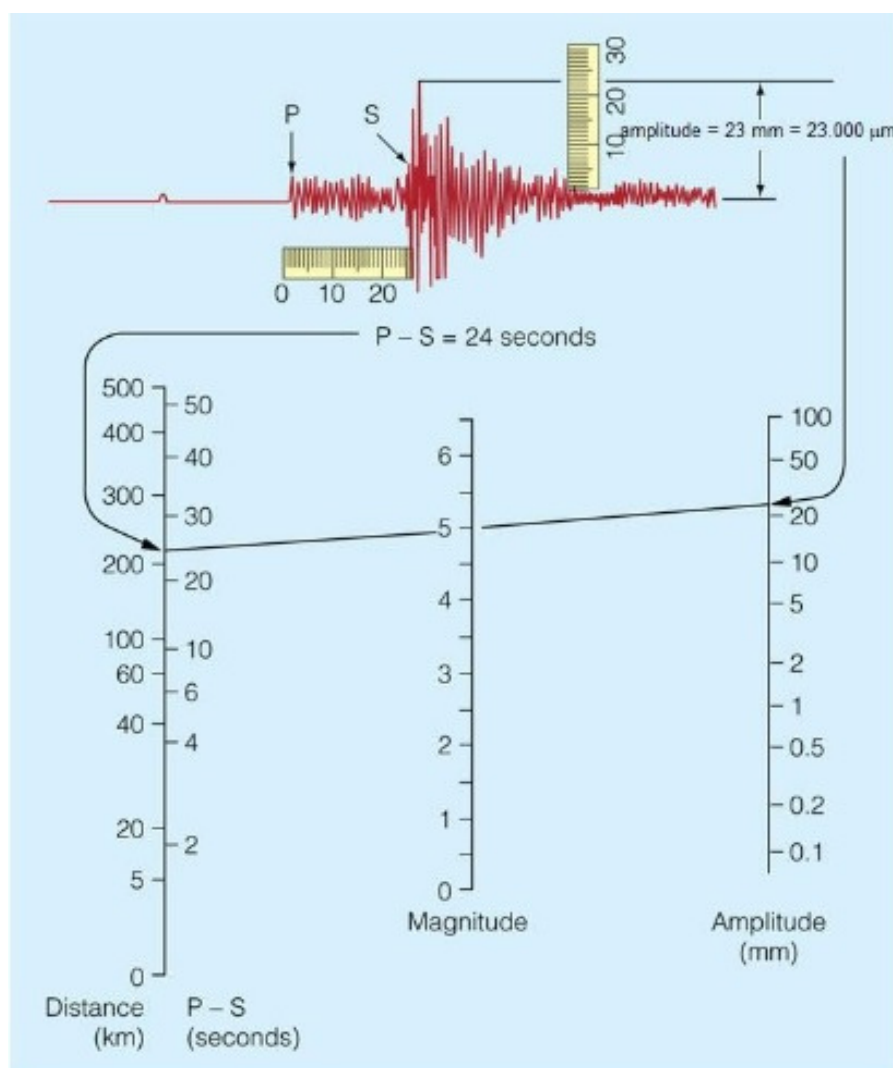


Fig. 1: Example of protractor to determine the local magnitude of an earthquake starting from the maximum displacement of the ground and from the epicentral distance in a certain territory.

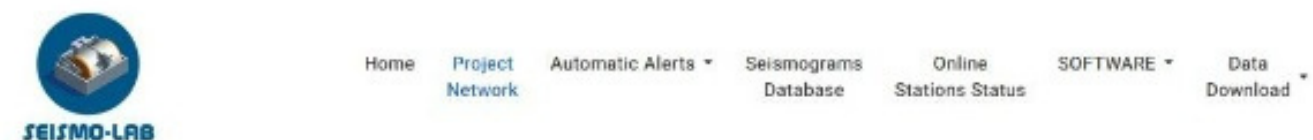
Appendix A. Procedure for acquiring waveforms from the SEISMO-Lab seismic network

The first core of the educational seismic network was developed within SNAC projects and has been empowered within SEISMO-Lab. It consists of over 50 seismometers installed in schools' headquarters at all levels in Greece, Turkey, Romania, Cyprus, and Italy.

The seismic data recorded by these sensors are gathered in the National Observatory of Athens servers. They are available to teachers, educators, and everybody who would like to investigate seismic activity in the Mediterranean area.



The web page of the project network - <https://seismolab.gein.noa.gr/project-network/> shows an interactive map where you can visualize the placement of the seismometers of the network.



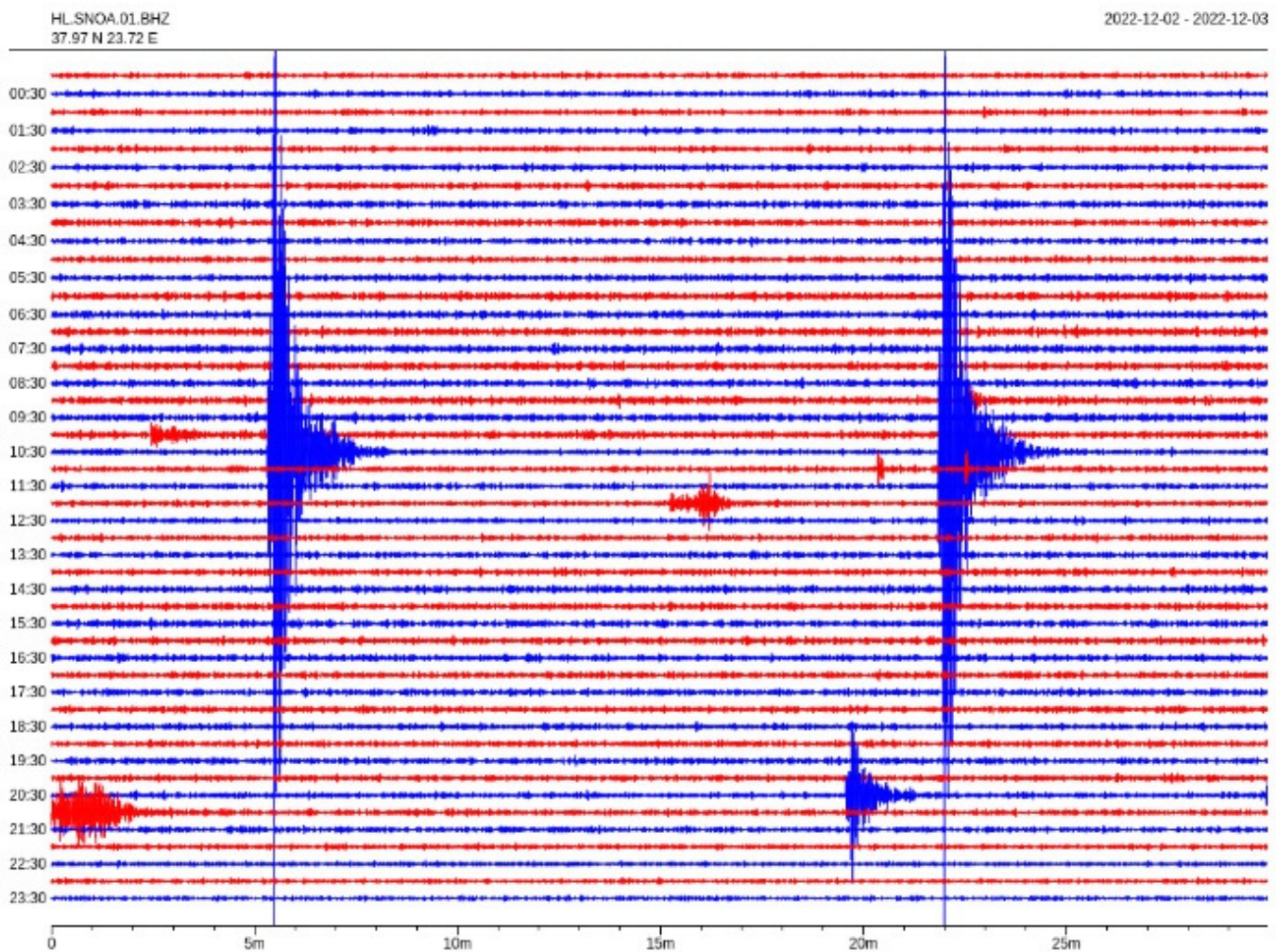
Project Network



Stations equipped with Raspberry Shakes

Map	Station	Code	Location	Latitude (N)	Longitude (E)	Elevation (m)	Daily Seismogram
-----	---------	------	----------	--------------	---------------	---------------	------------------

Clicking on one of the yellow or red triangles on the map and choosing the option Real Time Plotting you can visualize the daily seismic activity in real-time revealed by the chosen seismometer.



The National Observatory of the Athens seismic station on December 3rd, 2022 revealed the seismic activity in real-time. Note that the waveform of several lights occurred earthquakes; in particular, the two similar waveforms at 10:35 and 10:56 are related to two Magnitude 3,9 earthquakes that occurred around 45 kilometers from the seismic station. In technical jargon, such representation is called “helicorder.”



From the Seismograms Database web page - <https://seismolab.gein.noa.gr/seismograms-database/> - you can consult the seismic activity occurred in the past times.



To download the waveforms in numerical format from the network, you have to choose the option Schools Network Data - <https://seismolab.gein.noa.gr/data-search/> - from the menu Data Download.

Warning, the template appearing in this page is not active. You have to click on “Click here to go the data select builder” - <http://snac.gein.noa.gr:8080/fdsnws/dataselect/1/builder> down in the page to access to the real download page - see picture in the following page

DATA DOWNLOAD

In this section Data Download is available from all the network stations.

The download is available using the following builder:

SeisComp3 FDSNWS DataSelect - URL Builder

Time constraints

Start Time:

End Time:

Channel constraints

Network:

Station:

Location:

Channel:

Service specific constraints

Quality:

Minimum Length (s):

Longer Only:

Authentication:

Output control

Format:

No Data 404:

URL

<http://10.0.0.221:8080/Ethosws-dataselect/L/query?startdate=2011-01-01T00:00:00Z&enddate=2011-01-01T00:00:00Z&network=ABC.D&station=ABC.D&location=&channel=&quality=B&minlength=0.0&longeronly=&authentication=>

warning, this page is not active. You can open the real download page from this link and only if VPN GEIN-EDET is active.

[Click here to go the data select builder.](#)

Before you use the Data Select Builder, you must first connect to the E-Science Center VPN Network. VPN connection is available only for the project participants and the setup information has been sent by email.

Now you can type the date and the time of the beginning of the recording you want to download in the box **Start Time**, and the final ones in **End Time**.

In the **box Station** you have to type the acronyms of the station of which you want to download the recordings separated by a comma and a space.

Now, by clicking on the address in the box **URL**, you will download the requested file in **Mini-SEED format** (.mseed).

Time constraints

Start Time:

End Time:

Channel constraints

Network:

Station:

Location:

Channel:

Service specific constraints

Quality:

Minimum Length (s):

Longer Only:

Authentication:

Output control

Format:

No Data 404:

URL

<http://10.0.0.221:8080/Ethosws-dataselect/L/query?startdate=2011-01-01T00:00:00Z&enddate=2011-01-01T00:00:00Z&network=ABC.D&station=ABC.D&location=&channel=&quality=B&minlength=0.0&longeronly=&authentication=>

qui e qui vanno inserite le date (facendo clic sul calendario) e gli orari (digitandoli direttamente nella schermata) rispettivamente di inizio e fine della registrazione richiesta

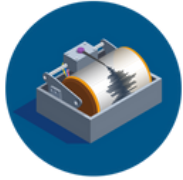
In questa casella vanno digitati gli acronimi delle stazioni sismiche dalle quali si vogliono estrarre le registrazioni. Gli acronimi devono essere separati tra loro da una virgola e uno spazio

una volta inserite le date e gli orari di inizio e fine delle registrazioni e gli acronimi delle stazioni sismiche, facendo clic su questo link si scarica il file con i sismogrammi

To visualize the waveforms in the so-gathered files, you can use an appropriate software like **SeisGram2K**, freely downloadable here:



http://alomax.free.fr/seisgram/ver70/SeisGram2K_install.html



SEISMO-LAB

Annex 4

Instructions, instruments and materials for Finding the velocity of P waves using real data collected from SEISMO-Lab seismometers

STAGE 1. ENGAGE

This stage is the part where the interest and motivation of the students in earthquake issues are increased and enriched. In this context, images related to the earthquake can be watched using digital media to increase the students' interest. For example, the earthquake that occurred in Elazig (Turkey) on 24/01/2020 and the news in the media in this context can be watched by students.

A small activity can be done to reveal the misconceptions that are thought to exist in students. This can be a test of misconceptions or a concept map activity.

STAGE 2. EXPLORE

At this stage, the dates and times of the sample earthquake events should be planned so that the students can find the velocities of the P wave. As an example, the earthquake data in the tables below are given to the students and the students are asked to fill in the blank data in the table. It is recommended to use google earth and swarm program to fill in these data.

Table 1. Finding time difference

Earthquake	Station Name	Country	City	Arrival time	Time difference

Table 2. Calculating the velocities of p waves $x=v.t \rightarrow V=X/t$ (km/s)

Station	Distance (x)	Time (t)	Velocity (v)

Example: Elazığ (Turkey) Earthquake

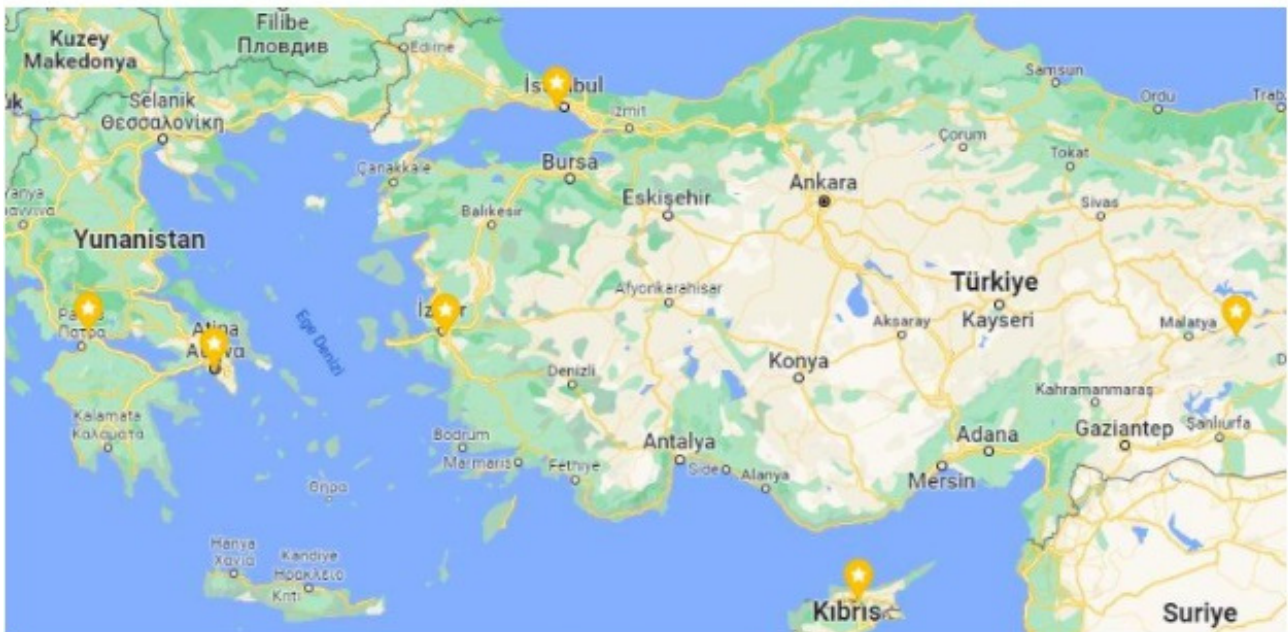
Location: Çevrimtaş , Sivrice- Elazığ

Magnitude: 6.7 Mw; 6.8 ML

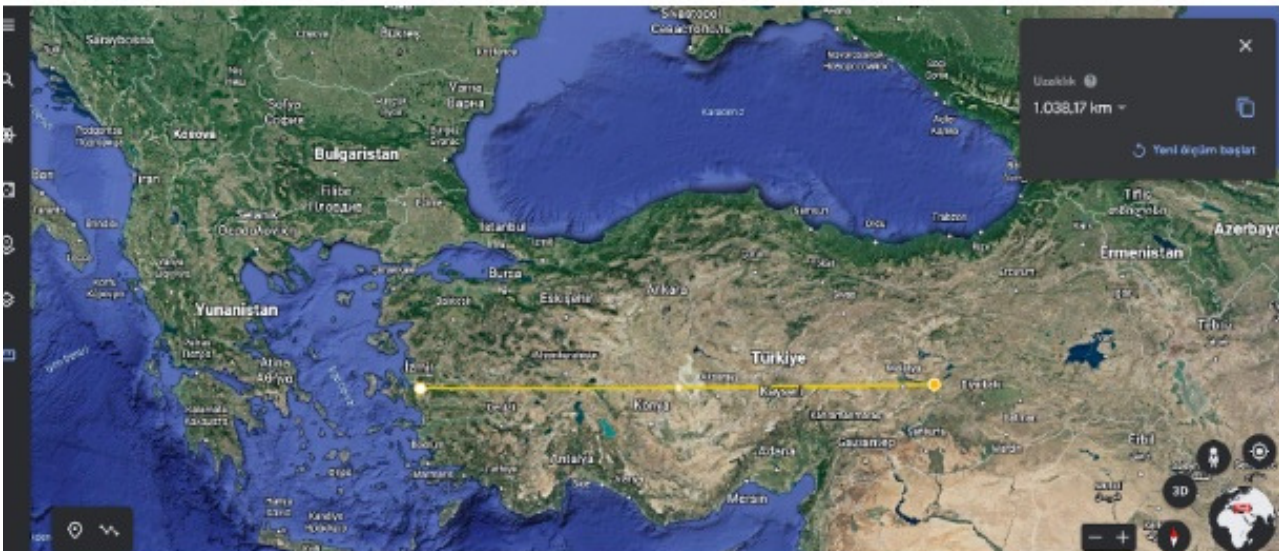
Local date: 24 January 2020

Local time: 20:55:11

The stations that will be used for the Velocity



Finding the distance from epicenter using Google Earth



Finding the time that the P waves reach the station (Using Swarm)

 <http://snac.gein.noa.gr:8080/fdsnws/dataselect/1/builder>

It is necessary to use the Swarm program to find out how long it takes for the P wave coming from the earthquake point to the stations.

To learn how to use the Swarm program, the SEISMO-Lab project web page must be visited. In this activity, it is assumed that teachers and students can use the swarm program. The screenshots below show how to find the times using the Swarm program.

SeisComP3 FDSNWS DataSelect - URL Builder

Time constraints	
Start Time	<input type="text"/>
End Time	<input type="text"/>
Channel constraints	
Network	<input type="text" value="AB,C?"/>
Station	<input type="text" value="ABC,D*"/>
Location	<input type="text" value="00"/>
Channel	<input type="text" value="BH?"/>
Service specific constraints	
Quality	<input type="text" value="B"/>
Minimum Length (s)	<input type="text" value="0.0"/>
Longest Only	<input type="checkbox"/>
Authentication	<input type="checkbox"/>
Output control	
Format	<input type="text" value="miniseed"/>
No Data 404	<input checked="" type="checkbox"/>
URL	
http://snac.gein.noa.gr:8080/fdsnws/dataselect/1/query?nodata=404	

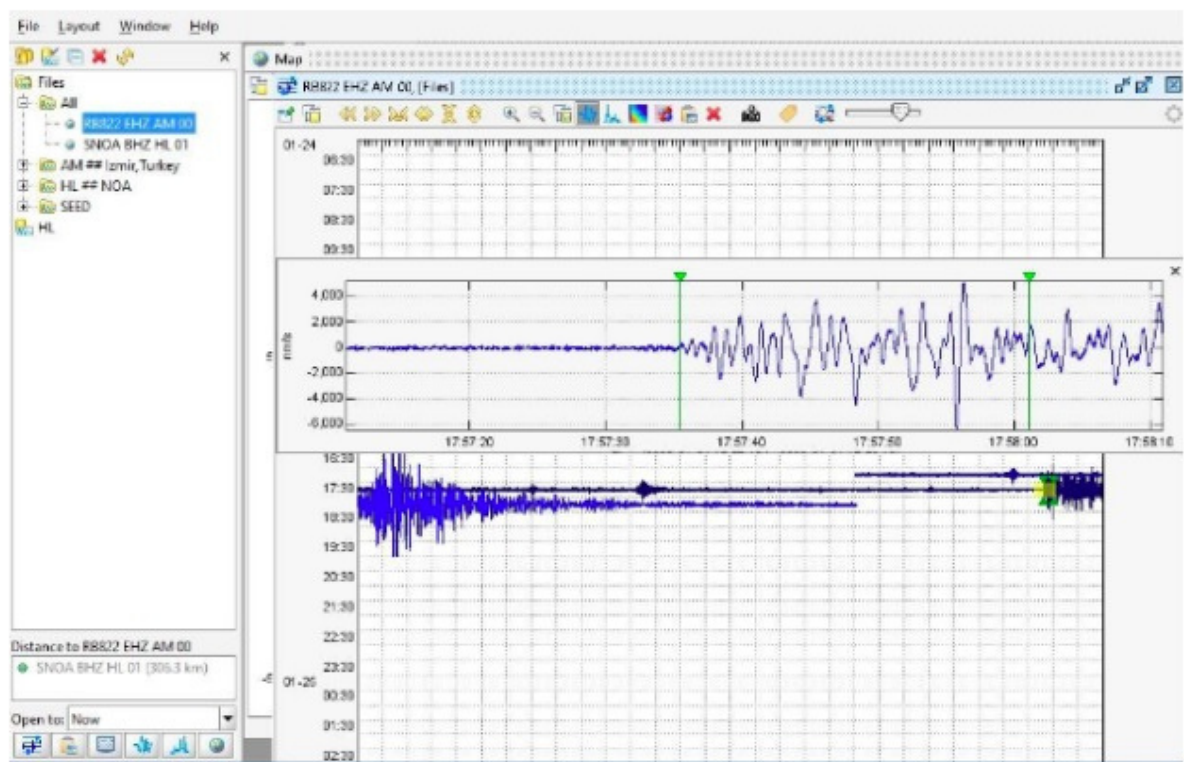
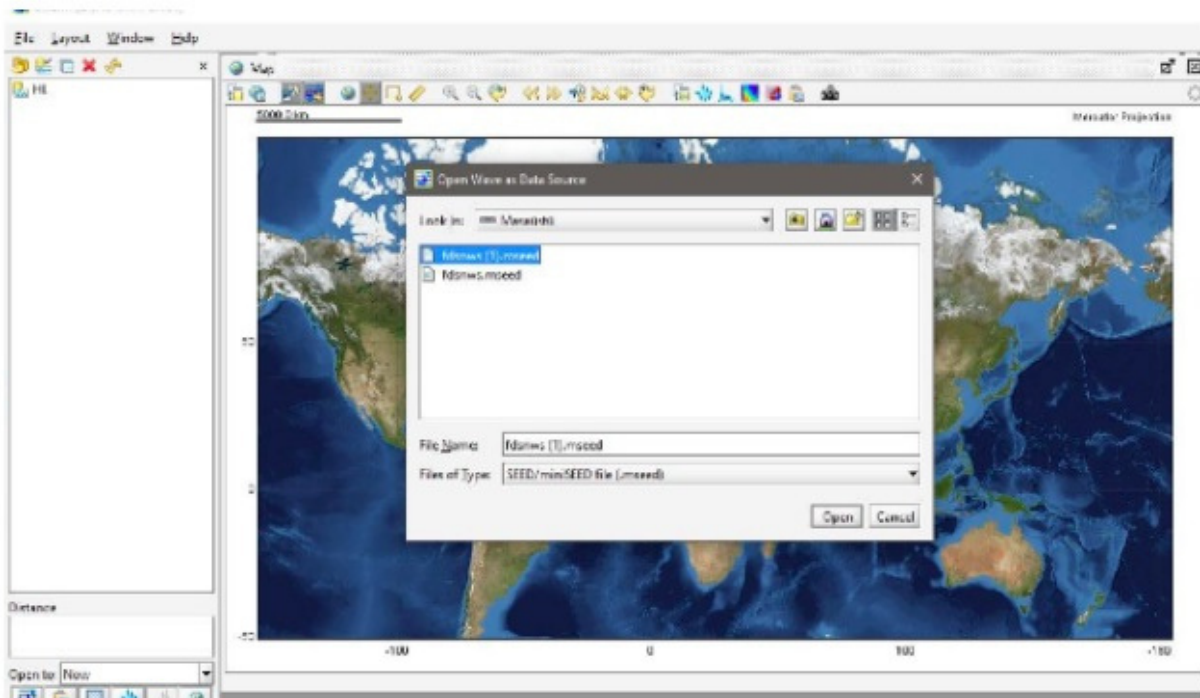


Table 1. Finding time difference

No	Station Name	Country	City	Arrival time	Time difference
1	SINST	TURKEY	ISTANBUL	20:57:23	132 s
2	RB822	TURKEY	IZMIR	20:57:35	145 s
3	R4EB6	GREECE	ATHENS	20:58:15	183 s
4	RF25A	GREECE	NAUPAKTOS	20:58:35	200 s

Table 2. Calculating the velocities of p waves $x=v.t \rightarrow V=X/t$ (km/s)

Station	Distance (x)	Time (t)	Velocity (v)
ISTANBUL	946	132	7,16
IZMIR	1038	145	7.1
ATHENS	1343,51	183	7,5
NAUPAKTOS	1506	200	7,53
LEFKOŞA	616	91	6,8

STAGE 3. EXPLAIN

Students can explain to the class what they explored from previous exploration stage. The teacher can correct them if they make any mistakes.

STAGE 4. ELABORATE

In this stage teacher can use open inquiry providing them with a new earthquake date to find the velocity of P waves coming to a station defined by the teacher.

STAGE 5. EVALUATE

Students can have a test to see the impact of this educational approach on their achievement on the earthquake concept.