Erasmus+ SMART Science and Mathematics Advanced Research for good Teaching

Co-funded by the European Union

THE PROJECT RESULTS IN SCIENCE

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Carlo Anti Villafranca di Verona IL PIACERE DEL SAPERE · UNIVERSITÀ DEGLI STUDI DI TORINO · TU Delft · RISORSE IN CRESCITA · ROMA TRE UNIVERSITÀ DEGLI STUDI · RADNOOTI · MIUR

SMART - Science and Mathematics Advanced Research for good Teaching

- to improve professional competences and to support innovation in the teachers' system of training through pedagogical solutions and innovative practices based on the new computer and multimedia technologies
- to provide tools and methodologies to facilitate the acquisition of STEM (Science, Technology, Engineering, Mathematics) skills - mathematical competence and basic competences in Science and Technology - through discussion and sharing with European partners and by introducing advanced technological tools in the teaching of Mathematics and Science to support learning
- to develop skills which can be used in order to contribute to a cohesive society, in particular to increase opportunities for learning mobility

SMART - Science and Mathematics Advanced Research for good Teaching

Expected results

- Definition of common educational models
- Development of a European database on training needs
- Development of a European database containing Best Practices
- Implementation of a dedicated international website
- Report on the results of the experimentation of laboratory modules
- Two open online courses for teachers:
  "Mathematical Modelling"
  "Observing, Measuring and Modelling in Science"

OBSERVING, MEASURING AND MODELLING IN SCIENCE

Objectives

The *scientific method* is the way to understand the physical origin of a phenomenon. To understand is different from *believe* or simply *known,* it means that we know about the causes of a phenomenon, we can make previsions and estimate the risk of failure.

It is a relatively common feeling in young students that science is restricted to laboratory practice and experiment means verify a law or the value of a constant. But this feeling lacks two essential steps of the scientific reasoning being to observe a phenomenon and to make hypothesis about causes which are the most exciting and creative part of the scientific reasoning.

In this course examples are presented in which the scientific reasoning is stimulated starting from relatively common and day-life phenomena.

OBSERVING, MEASURING AND MODELLING IN SCIENCE: TOPICS

- ✓ **Methods in Science**
  - Teaching with practice
  - Scientific reasoning
  - Measure and uncertainty
  - Modelling and data fitting
- ✓ **Energy in Science**
  - Mechanics
  - Chemistry
  - Biochemistry
- ✓ **Practical optics: from reflection to diffraction**
  - Reflection and refraction
  - Diffraction
- ✓ **Earth Science**
  - Earthquakes
  - Water and sands

OBSERVING, MEASURING AND MODELLING IN SCIENCE

Materiali:

- Presentazioni su aspetti generali
- Schede di semplici esperimenti di laboratorio
- Percorsi sperimentali completi
- Video

1. Methods in Science:

Teaching with practice

- Lab methodology
- The mole concept: counting without counting

Scientific reasoning

- Deductive Reasoning: the example of reflection laws.
- Inductive reasoning: Flower reproduction.

Measuring and uncertainty

- The role of uncertainty
- Error propagation: the Montecarlo method

Quantitative modelling and data fitting

- The refraction law (Snell's law)
- Gas dilatation
- Parabolic fall

OBSERVING, MEASURING AND MODELLING IN SCIENCE

2. Practical optics:

Reflection and refraction:

- Deflecting light I: the transparent sheet
- Deflecting light II: the water surface
- Bending light: the waveguide
- Zooming into a glass of water
- A thick lens from a glass of water

Diffraction

- Single Slit diffraction Page
- Thin as an hair Page

OBSERVING, MEASURING AND MODELLING IN SCIENCE

3. Earth Science: Seismo box

Earthquake
Water in sands

4. Energy in Science: Mechanics → energy conservation

→ revealing friction

Chemistry → energy from batteries
Biochemistry → energy from food
→ leaf at work

Methods in Science: Lab teaching methodology

Traditional ("Transmissive") teaching

Traditional teaching is based on a «transmission» approach; the teacher, who is the owner of knowledge, transmit it to the learners. The learners memorize at their best what the teacher says, reproduce it on request, and learn to put it in practice, by carrying on exercises of standard type

This teaching style is based on the ideas that knowledge is essentially theoretical knowledge, that one teaching style fits all learners, that the teachers' role is the active one, while the learners are there to be «filled up» with knowledge.

What does "Lab Teaching" mean?

Laboratorial teaching relies instead on the idea of setting up an environment (space, time, relationship between teacher and learners and among learners) in which learners are active and interactive, so that they can, under teacher coaching and supervision, build their own knowledge and competences. They do that by exploration (direct or by net tools), peer confrontation, design and realization of experiences in team with peers, measurements, collection of results, analysis and interpretation of data, reflection on experiences.

Not just experiments therefore, but logical and communicative skills too, the ability to self-evaluate and confront with others, to properly express one’s point of view and to put one’s ideas and opinion under scrutiny.

Methods in Science: Scientific reasoning

Introduction: to believe, to know, to understand

Believe, Known Understanding: three steps toward comprehension about a phenomenon
Our comprehension about a physical phenomenon could derive from three different approaches:

- **to believe**
- **to know**
- **to understand**

To *believe* has little to do with science, it is related to our confidence on some-one: ourself, our parents, our friends, our teachers, and so on.

Methods in Science: Scientific reasoning

Introduction: to believe, to know, to understand

The second level, *to know*, is related to our direct experience, even if experience can give a stronger support to our comprehension about a phenomenon, our interpretation could be biased due to:

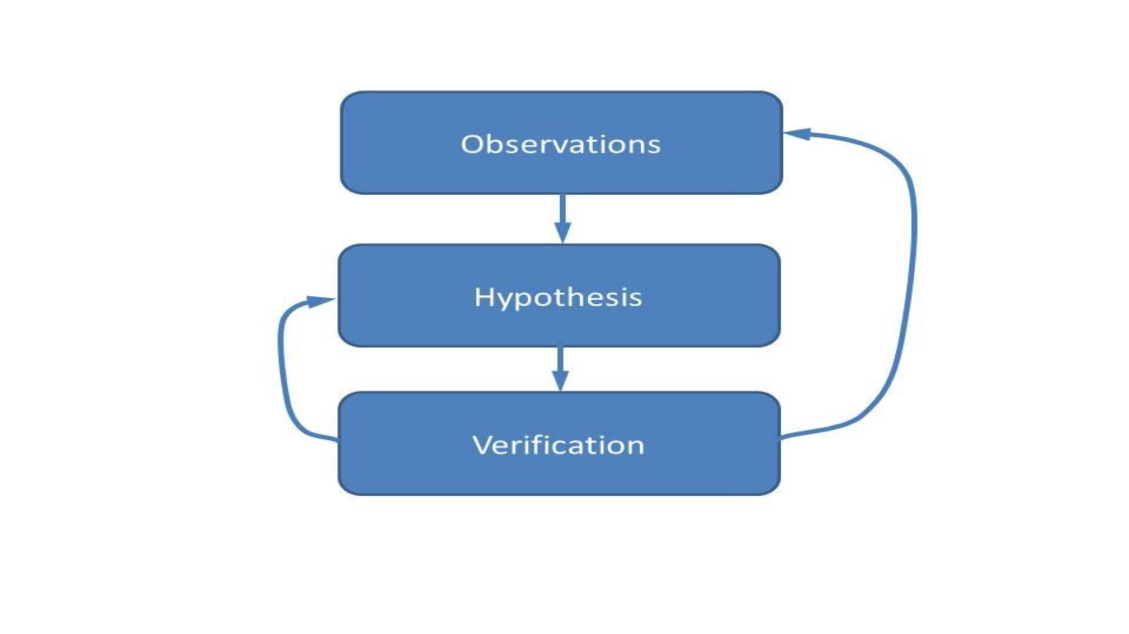
- **limited experience: If we witness a rare event we are prone to give a high probability to it;**
- **selective attention: focusing on selected aspect of a phenomenon, neglecting others, this may give a distorted view of a phenomenon.**
- **measurement uncertainty: experimental results may be spread due to the stochastic nature of the observed phenomena, we need a way to deal with uncertainty and evaluate the risk of failure;**
- **experimental errors: errors in the experimental set-up, interpretation of the data, may bring to wrong conclusions.**

Introduction: to believe, to know, to understand

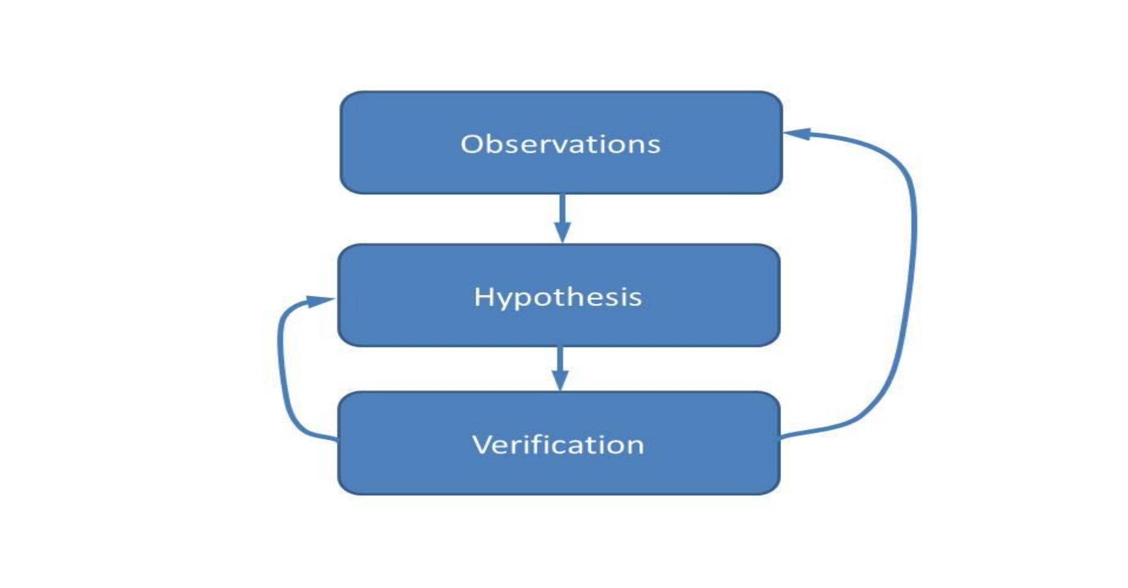
Understanding is different from *believe* or simply *known:* it means we understand the causes of a phenomenon, so we can make previsions and estimate the risk of failure.

The scientific method is the way we can achieve such understanding. The scientific method proceeds by three steps:

Observation, make hypothesis and verification in a continuous cycle: this is an always ongoing process with which science continually tests its laws, revise a theory, review his results.



Methods in Science: Scientific reasoning



In this process *making hypothesis* represents the fascinating and creative part of the Science. Often this steps is skipped while we propose to students to verify the value of a physical constant, to apply a physical law (also if derived by a rigorous mathematical reasoning) to solve an exercise. Verify and apply, without scientific reasoning may results in a trivial *believe* on the textbook, on the teachers, etc..

Methods in Science: Measure and uncertainty

The uncertainty is an intrinsic factor measuring any physical quantity. The uncertainty characterizes the quality of a measure and it should be reported along with the measured value as without this information the results cannot be compared with others, or with reference values.

Scheda sintetica di un semplice esperimento di misura: La misura dell'altezza di uno studente in piedi e sdraiato

Situazione in cui i dati sperimentali hanno fluttuazioni molto grandi

E' possibile affermare che c'è una differenza tra i due valori?

Methods in Science: Measure and uncertainty

Scheda sintetica di un semplice esperimento di misura: La misura dell’altezza di uno studente in piedi e sdraiato

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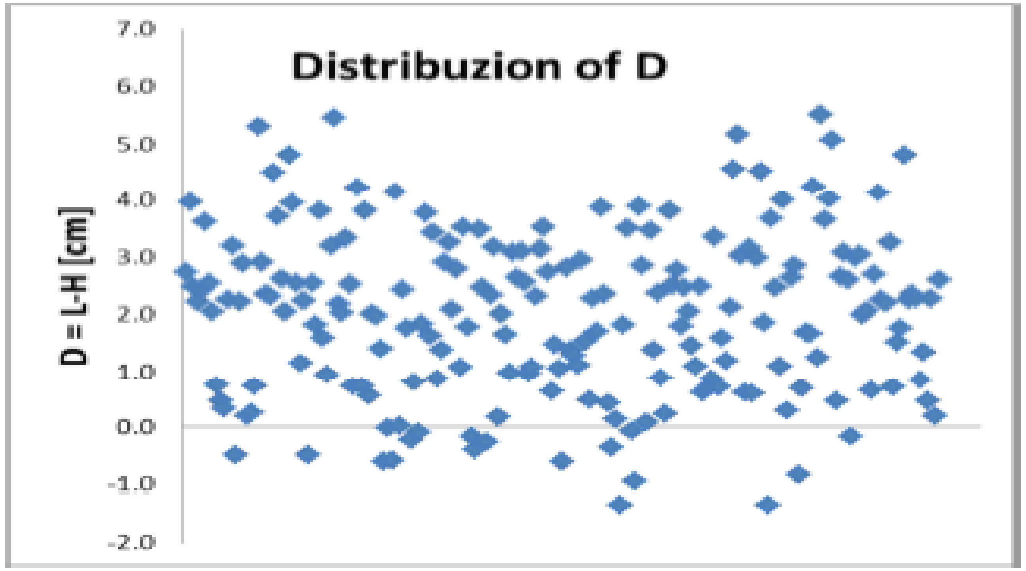
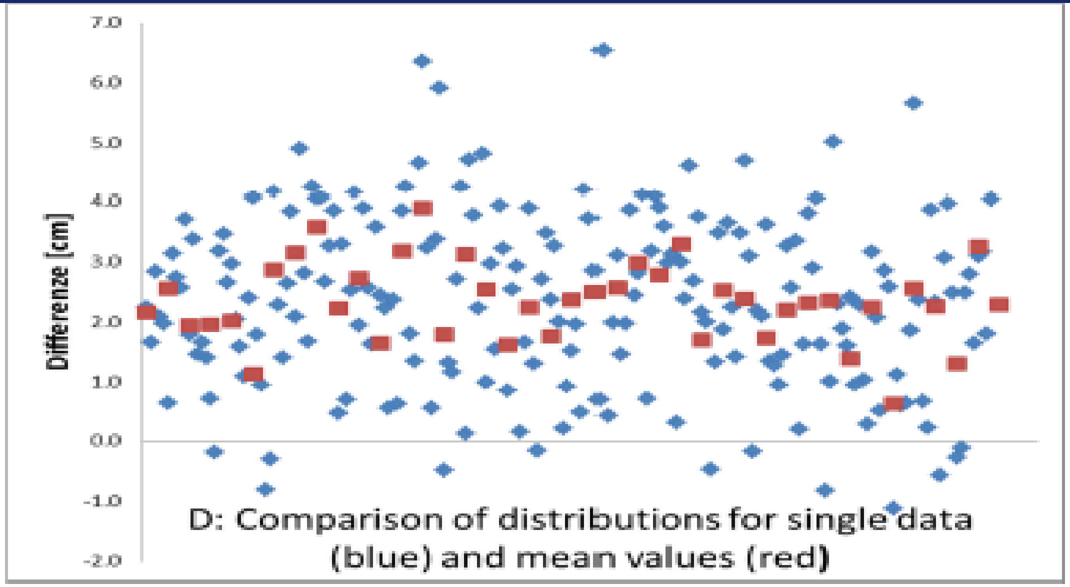




Methods in Science: Measure and uncertainty

Montecarlo Method

Uncertainty is an intrinsic factor, cannot be eliminated, measuring any physical quantity. It assesses the quality of a measure and must be always associated with an experimental value.

The analytical calculation of uncertainty for the derived quantities can be complex and requires familiarity with the derivatives.

The Montecarlo method provides a way to quickly estimate the errors in an empirical way to simulates the effect of a statistical distribution.

Here it is implemented using a spreadsheet.

Methods in Science: Modelling and data fitting

- Refractive index of water
- Temperature gas expansion
- Parabolic fall
- Bacterial counting procedures M1
- Bacterial counting procedures M1
- Bacterial counting procedures M1

Title:	The Parabolic fall
Abstract:	The free fall of a real object, as a basket ball, is quantitatively investigated using Tracker[1] software, an excellent resource for experiments in laboratory as well in everyday experiences.
Matter (one or more):	Physics
Required time N. of students (minimum)	h. 3 # 1
Activity	Measurement, video-recording, data analysis
Synthesis of activities	• Video-recording of the throw of a ball • Video-analysis of the trajectory with Tracker software • Interpretation of the charts and data obtained
Instrumentation	• A basketball or other infrangible object • Graduated rod (dipstick) • Video recording camera (i.e. Smartphone or webcam) • PC with Tracker software
Knowledge and abilities (pre-requisites)	• Knowledge of parabolic motion laws • Use of Tracker software • Charts analysis
Knowledge and abilities (objectives)	• Practical investigation of the trajectory of a launched body with initial horizontal velocity. • Understanding the velocity decomposition (along x and y) • Comparison of experimental and theoretical value of gravity acceleration g • Highlight friction effect
Security issues (if required)	None
Authors	Celora Marina
Notes	Original text by prof. M. Celora on LS-OSAlab
References	[1] Tracker is a free software (GNU license) and can be downloaded by this link: http://www.cabrillo.edu/~dbrown/tracker/ A user guide is available to this link: http://www.cabrillo.edu/~dbrown/tracker/tracker_help_it.pdf
Version	01 - data

Introduction and aims

Every time we throw an object (is it a ball, a wad of paper etc…) we experience the effect of gravity on its motion: the object falls downward after a certain distance following a curved path. The moment in the body leaves our hands the forces acting on the object are the gravity, which acts downward, and the friction. Mathematical calculation of the trajectory, in case of negligible friction, is a classical exercise of physics courses.
Here is presented the possibility to practically examine the trajectory of real objects in the everyday life and compare experience with theory using common tools (camera, portable phone, webcam) and easy to handle software.

Set-up

The experiment consist of:

- launching an object,
- Making a video of the trajectory
- Analyze the video to get quantitative information about the trajectory and motion equation.

The experimental setup is simple and requires to:

- fix horizontal and/or vertical references to calibrate the scales in the video (Figure 1).
- Record the video perpendicular to the trajectory in order to avoid/reduce parallaxes effects. The object must have a color distinguishable from the background
- Import the video on a PC and read the video using Tracker software.
- Calibrate the geometry
- Get the trajectory as a function of time.

Discussing the set-up with the classroom allows for better understanding why and how to better manage the experiment and the data.

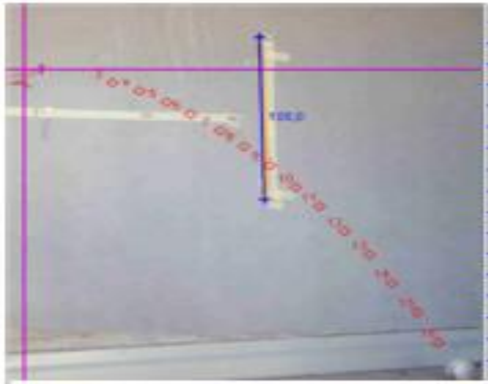
Data collection

The ball used for the experiment must have a color easily distinguishable from that of the background. Pay attention to throw the ball horizontally, i.e. parallel to the wall. With the smartphone (or a video-camera) record the whole trajectory of the ball. To reduces errors it is advised to use a tripod or fix the camera on a base.
Import the video on a PC with Tracker software installed and:

- select the usable photograms. It is a crucial part of the analysis: choose the first photograph corresponding to the exact moment when the ball is free (i.e. it is not in contact with the hands of the pitcher).
- The last photograph corresponding to the moment when the ball reaches the ground;
- Use the vertical dipstick to calibrate the scale;
- Establish the reference system. It is important that the x-axis is parallel to the ground.

Data analysis

Data analysis will be entirely done with Tracker. As a first step Tracker must recognize the ball (or any other object) as a "point mass" and its motion as the "trajectory". To this end select "**Point Mass**" and select the ball in the first photogram; then draw the trajectory, photogram after photogram.
Tracker gives also the possibility to automatically draw the trajectory but the manual method (photogram by photogram) could be more accurate. Comparing the extraction of different groups working on the same video may stimulate the discussion about "measurement uncertainty"
An example of the results collected at the end of these operations are reported in **Figure 1** and **Figure 2**:



t	x	y
0	0,535	1,069
0,033	14,97	-0,535
0,067	27,801	-4,277
0,1	41,702	-8,554
0,133	54,533	-13,901
0,167	67,364	-20,851
0,2	78,592	-28,336
0,233	92,492	-38,494
0,267	103,72	-48,117
0,3	116,016	-59,345
0,333	128,313	-72,711
0,367	139,54	-84,473
0,4	151,302	-99,977
0,433	163,064	-114,947
0,468	173,757	-132,59
0,502	185,519	-150,233
0,535	195,677	-168,411

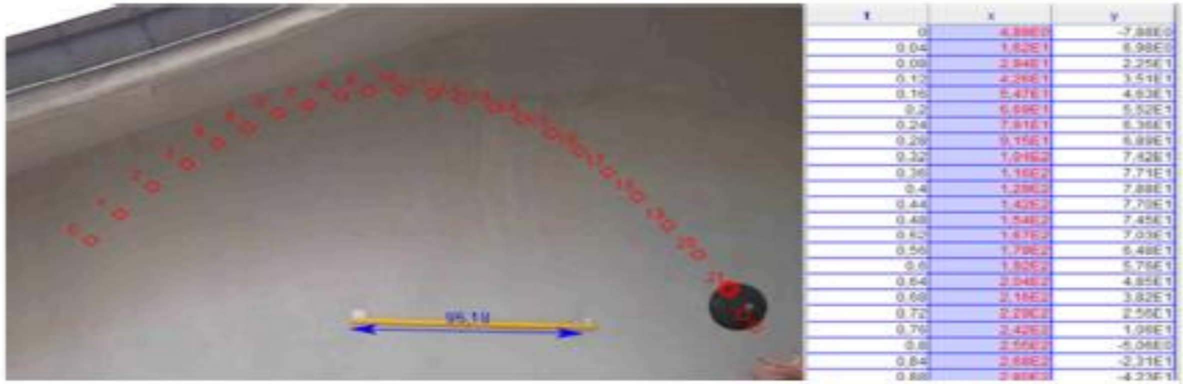
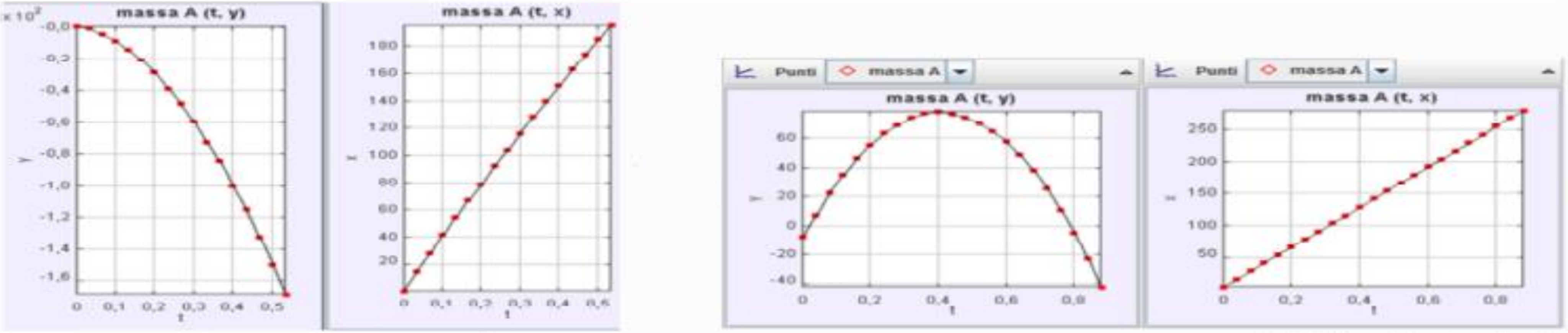


Figure 1 – examples of data collection: horizontal launch (left), oblique launch (right).

Tracker will provide the positions of the object (x,y) as a function of time (t).
The program provides the graphs describing the motion along the horizontal (y) and vertical (x) directions: *y=y(t)* and *x=x(t)* f (**Figure 2**) and regression curves (least-square) through the data from which quantitative parameters can be obtained.



$x = 3.64t + 0.05$ $y = -4.92t^2 - 0.56t - 0.02$ $x = 3.13t + 0.04$ $y = -5.30t^2 - 4.28t - 0.09$

Figure 2 – Curve parameters horizontal launch (left), oblique launch (right).

Graphs show the two different behaviors of the motion along the horizontal and vertical directions, rectilinear along y: y(t) ~ t, uniformly accelerated along x: x(t) ~ t^2

Different object may behave differently: light balls, as an example, may depict friction effects.

Data can be exported to spreadsheet or other data analysis software for more accurate analysis. Comparing results of repeated launches and/or the parameters obtained by different groups analyzing the same video will allow to define the uncertainties on the parameters and recognize the characteristics of the motion.

Parabolic fall

Equazione generale	Equazione nel caso 1	Equazione nel caso 2
$x = v_{ox}t + x_o$	$x = 3.64t + 0.05$	$x = 3.13t + 0.04$
$y = -\frac{1}{2}gt^2 + v_{oy}t + y_o$	$y = -4.92t^2 - 0.56t - 0.02$	$y = 5.30t^2 - 4.28t - 0.09$
$y = -\frac{g}{2v_{0x}^2}x^2 + \frac{v_{0y}}{v_{0x}}x + y_0$	$y = -0.4x^2 - 0.02x + 0.003$	$y = -0.54x^2 + 1.41x - 0.15$

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Table 2: example of data analysis.

Parabolic fall

Discussion

One would expect the gravity constant g=9.81 m/s^2, the obtained results rarely will be equal. As an example in the analysis given here *g*=10.6 m/s^2 with an error around 8%. Interesting: this error may ranges from 4 to 10% for the same video analyzed be different groups. Discussion about the origin of these discrepancies is instructive as allow understanding the "errors" as normal contributions in the experimental knowledge. Properly managing the uncertainty is a fundamental step of scientific knowledge.

Main sources of errors could be:

Calibration of distances,

Geometrical aberrations

Definition of mass center

Friction effect

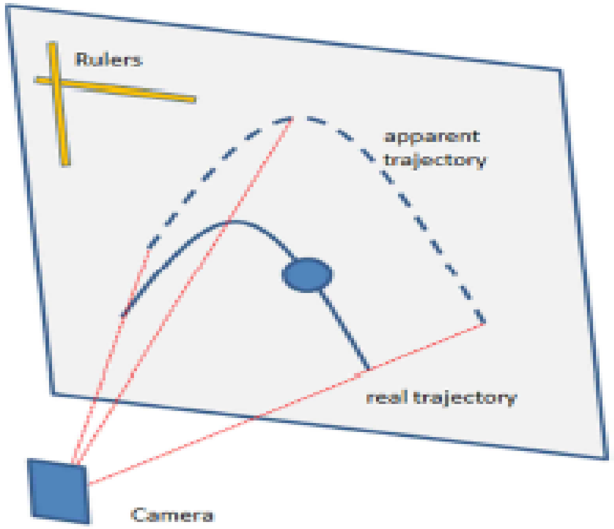


Figure 3: Parallax errors during video recording

Conclusions

With this experience students can easily find a confirm of the theoretical notions about the parabolic motion. The motion laws and the trajectory obtained by data analysis correspond to the previsions. This simple experience also implies the use of one or more software necessary for data elaboration and analysis.

Practical optics: from reflection to diffraction

Reflection and refraction

- Deflecting light I: the transparent sheet
- Deflecting light II: the water surface
- Bending light: the waveguide
- Zooming into a glass of water
- A thick lens from a glass of water

Diffraction

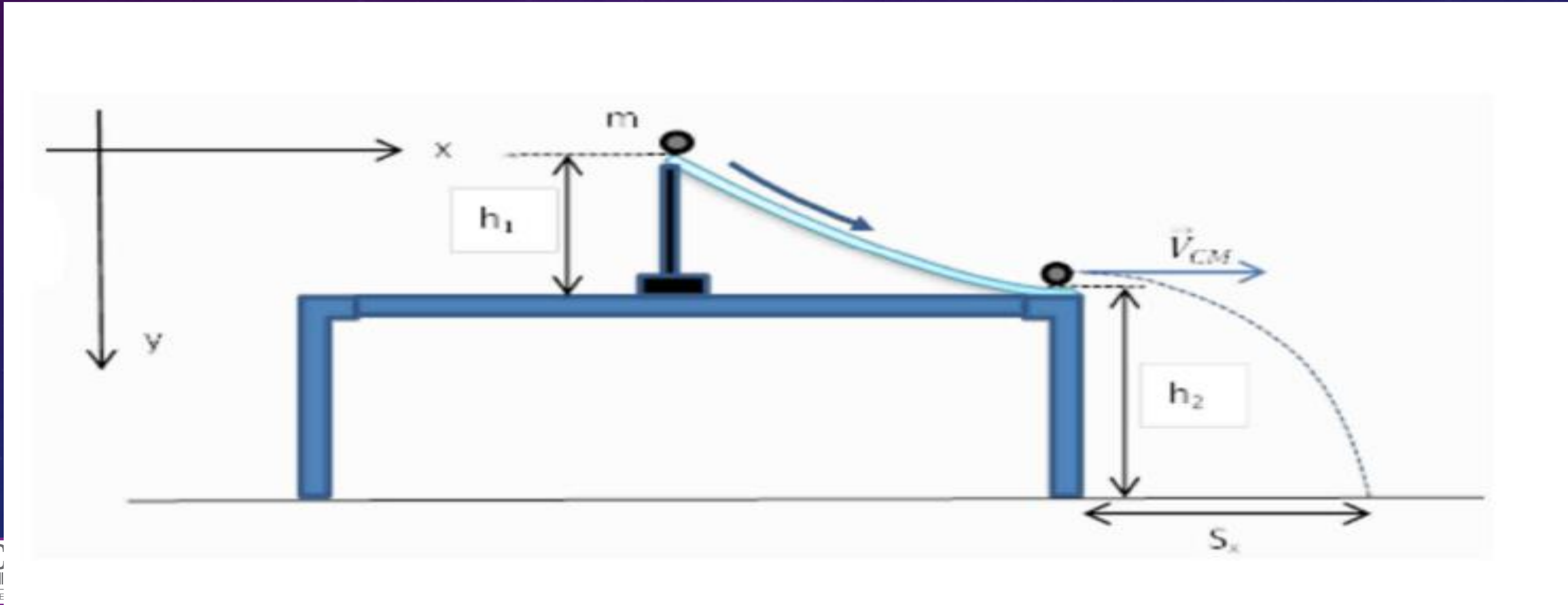
- Single Slit diffraction Page
- Thin as an hair Page

Energy in Science

Mechanics:	**energy conservation**
	revealing friction
Chemistry:	**energy from batteries**
Biochemistry:	**energy from food**
	leaf at work

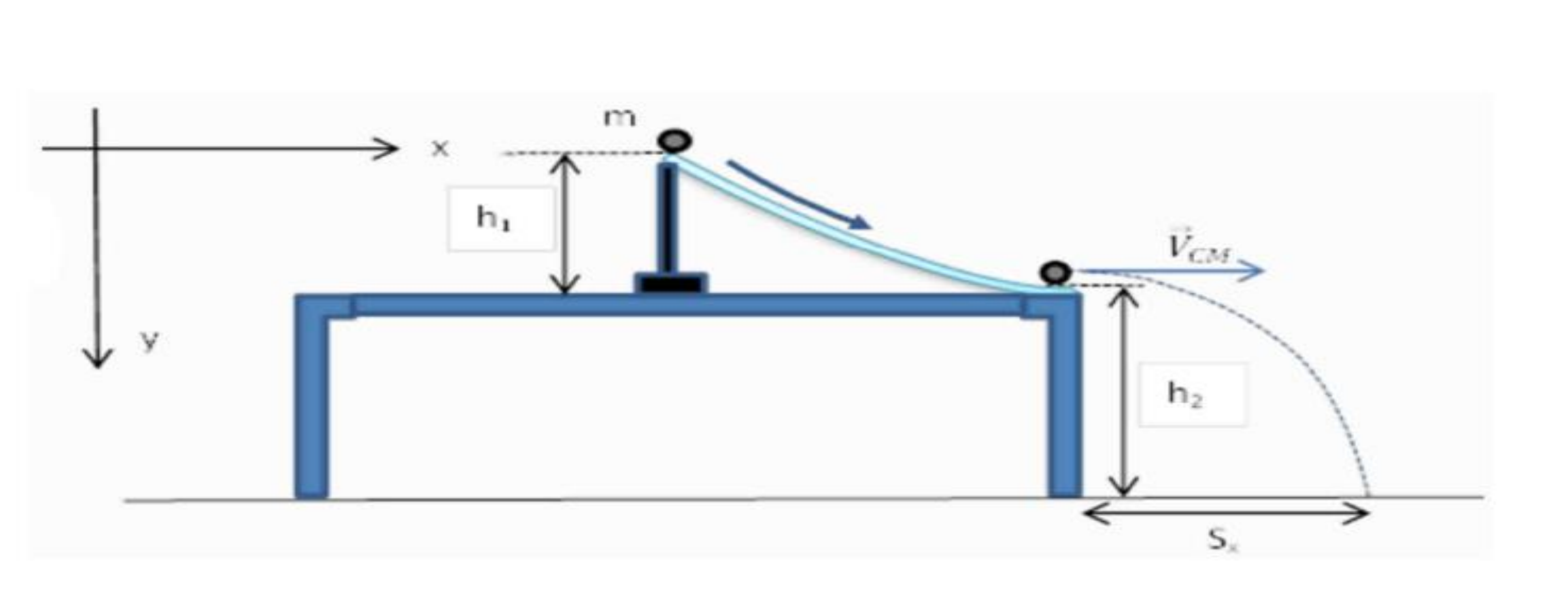
Energy in Science - Mechanics: energy conservation

simple experiment addressed to consider the mechanical energy (potential and kinetic) and understand how the energy conservation principle allows to individuate the rotational contribution to the total energy in case of an extended body.



Energy in Science - Mechanics: revealing friction

Friction is ubiquitous in the real life which major effect, in a mechanical system, is wasting energy so preventing the energy conservation. Here the experiment described in energy conservation is modified in order to evidence the effect of friction experimentally quantify the energy waste.



Energy in Science

Chemistry: Electricity from batteries

This unit develops a laboratory teaching lesson on redox reactions and their use to produce energy studying Daniell battery based on the reaction:

$$CuSO4 + Zn \rightarrow Cu + ZnSO4$$

Biochemistry: Energy from food

Here is shown hown juk food can be used to update approach to calorimetric measurements and thermodynamic laws.

Objective: determine the heat of combustion of prepackaged sweet or salty snacks using a calorimeter designed by students

Energy in Science

Biochemistry: Leaf At Work

From where the leaf take energy to survive and grow up? The role of light and photosynthesis processes are experimentally investigated and understood

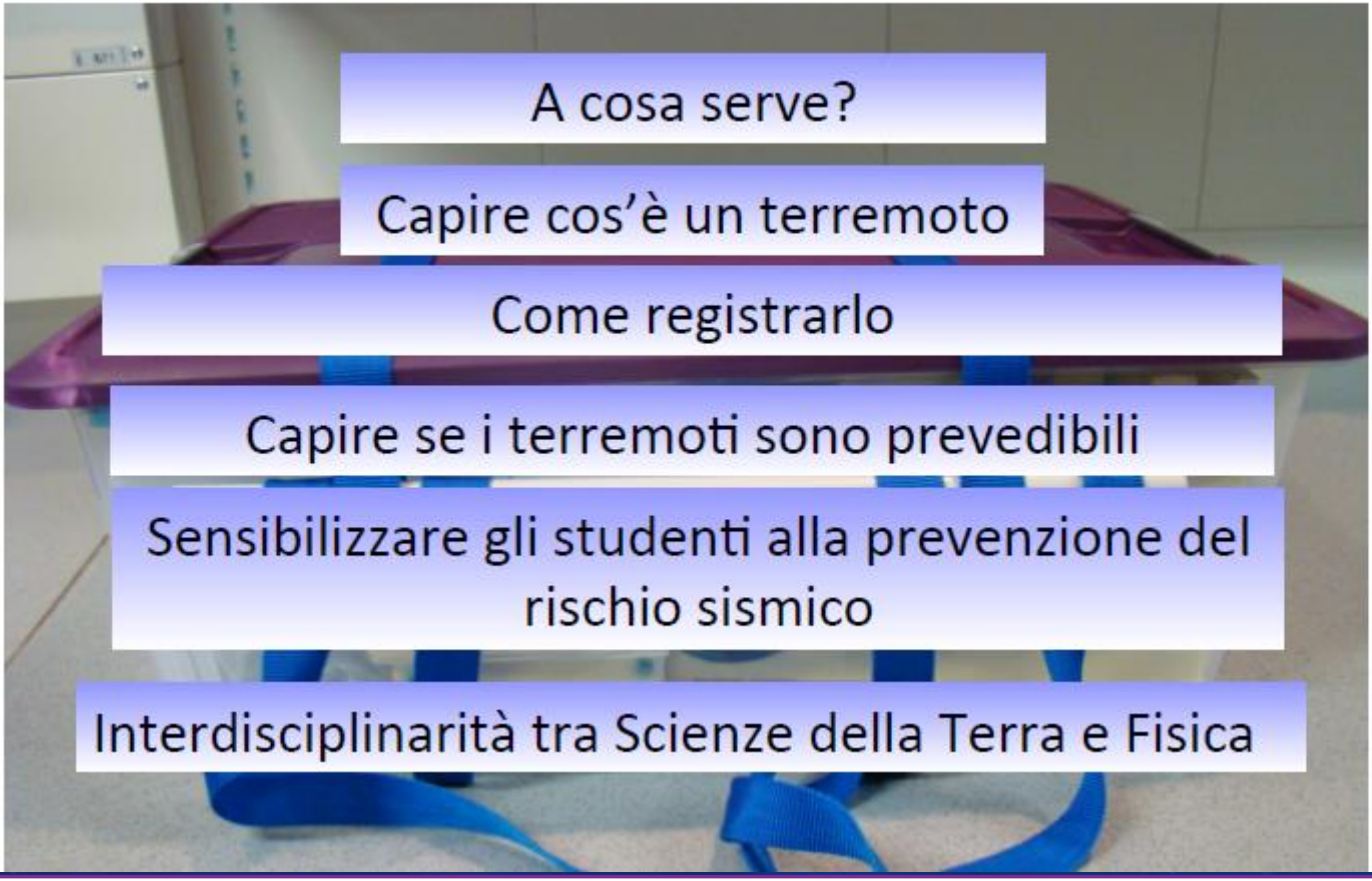
Earth Science: Seismo box

Earthquake:

what it is?
It is predictable
Consequences

Water and Sand

Kit Seismo Box 'Terremoto fai da te'



A cosa serve?

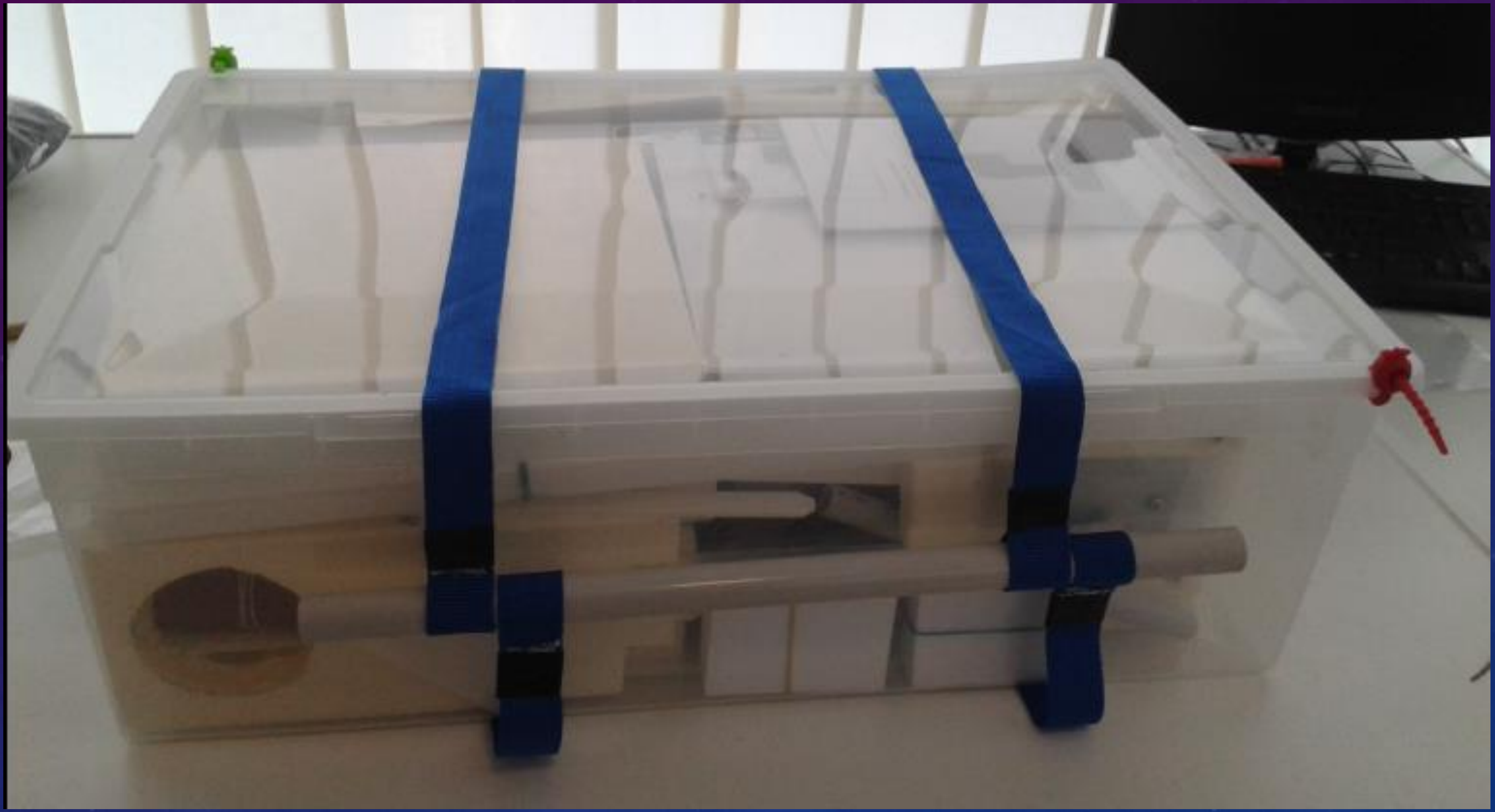
Capire cos'è un terremoto

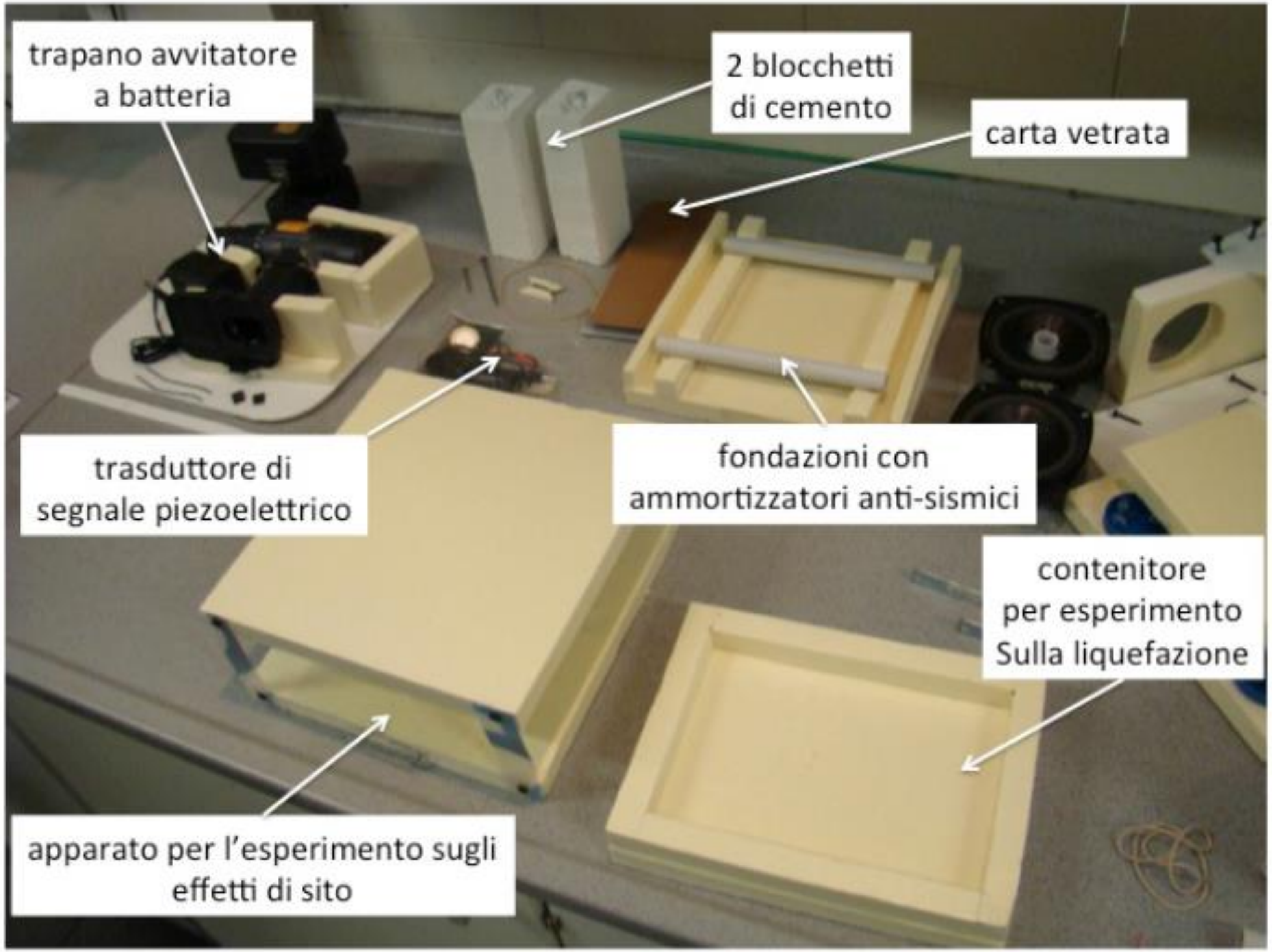
Come registrarlo

Capire se i terremoti sono prevedibili

Sensibilizzare gli studenti alla prevenzione del rischio sismico

Interdisciplinarità tra Scienze della Terra e Fisica




trapano avvitatore
a batteria
2 blocchetti
di cemento
carta vetrata
trasduttore di
segnale piezoelettrico
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per esperimento
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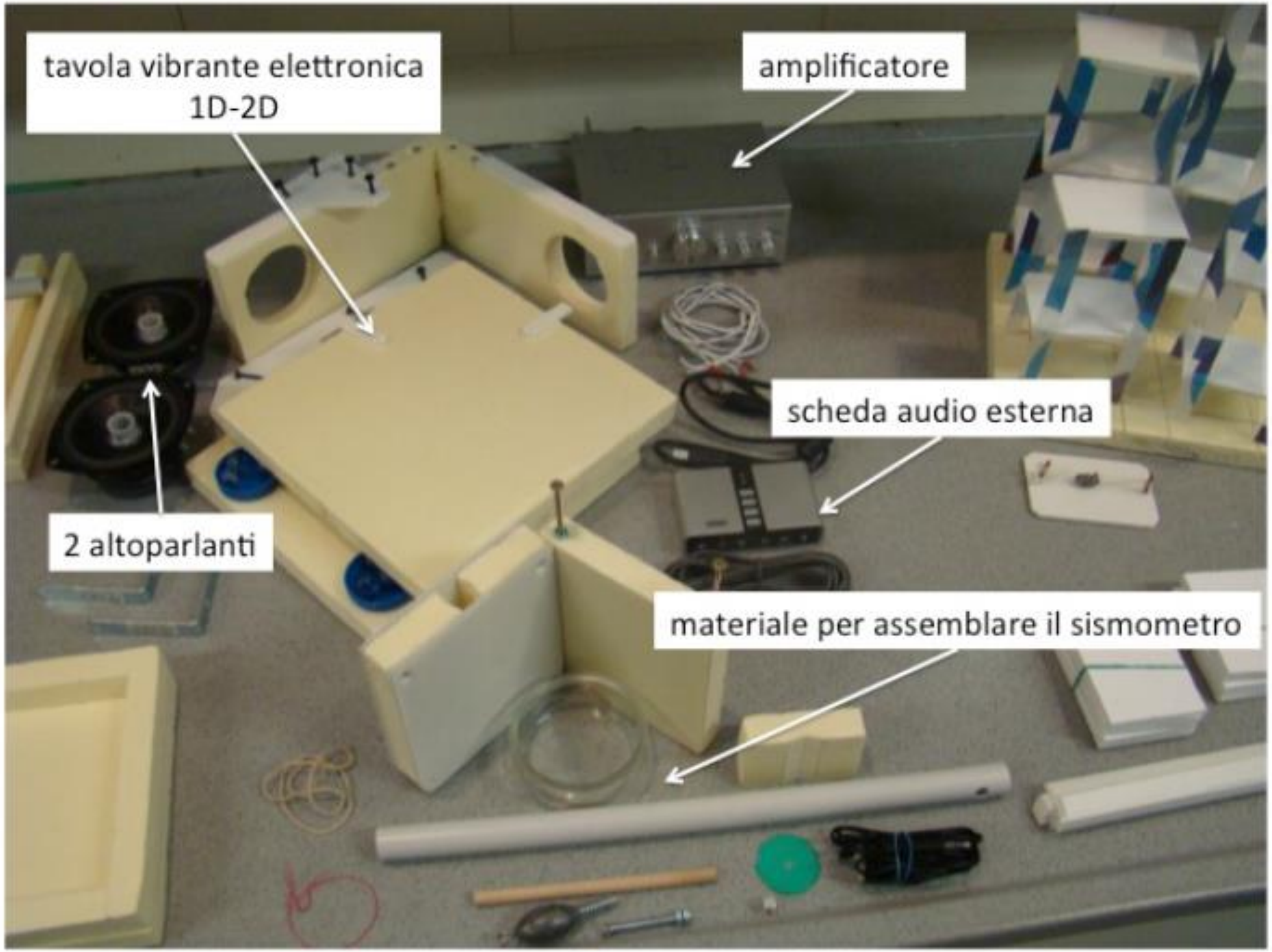
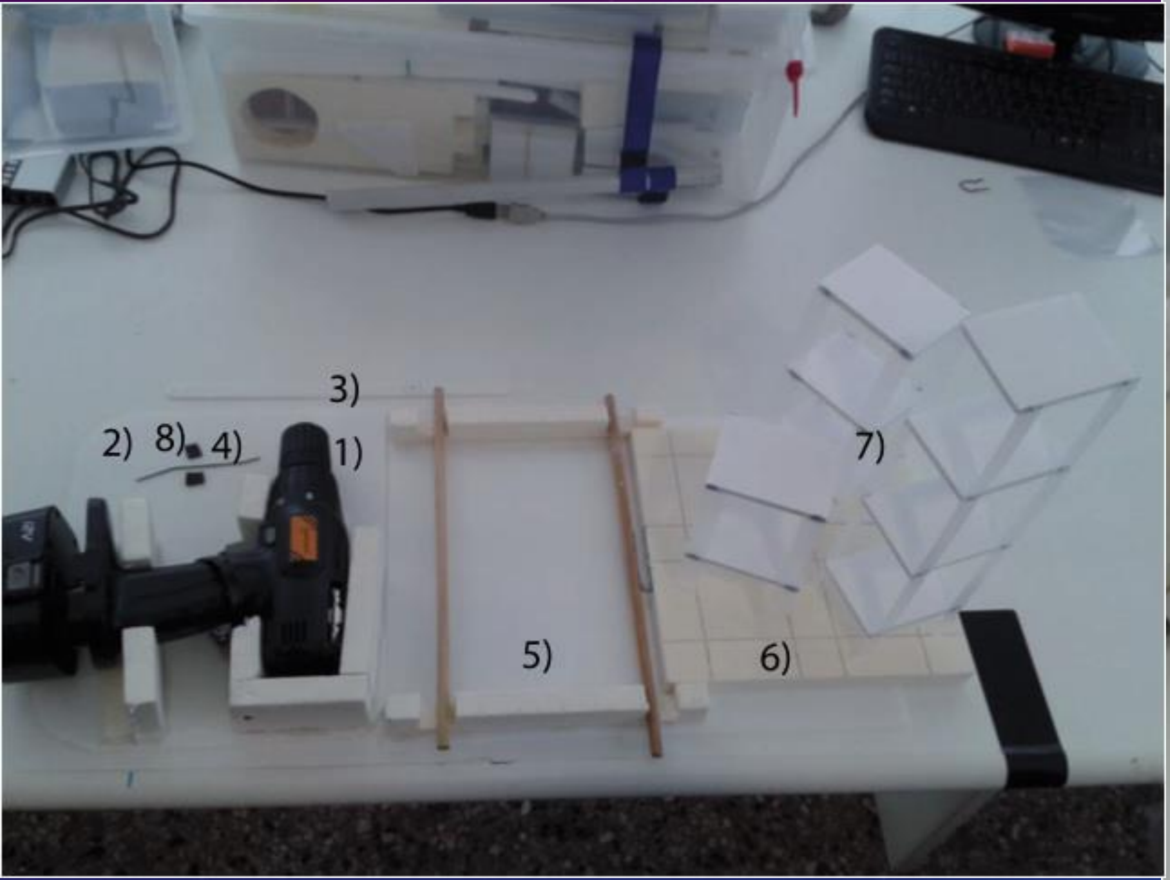


tavola vibrante elettronica 1D-2D
amplificatore
scheda audio esterna
2 altoparlanti
materiale per assemblare il sismometro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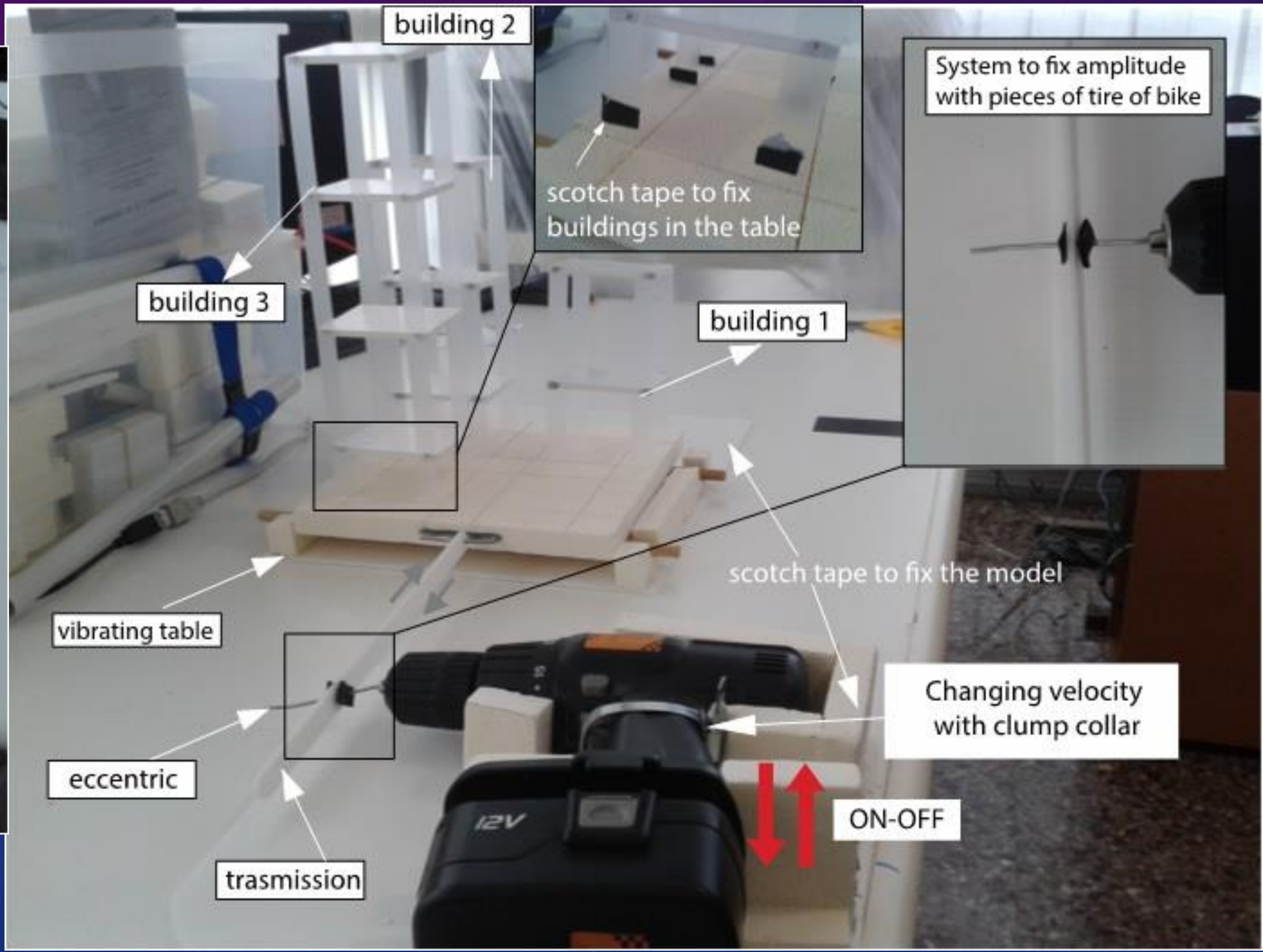
building 2
building 3
scotch tape to fix buildings in the table
System to fix amplitude with pieces of tire of bike
building 1
scotch tape to fix the model
vibrating table
Changing velocity with clump collar
eccentric
ON-OFF
trasmission