Settimio Mobilio,

University of Roma Tre, *The project results in Science*

Settimio Mobilio illustrates the aims of the SMART Project, which are:

- 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

Consequently, the project expected results are:

- 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 are being produced: "Mathematical Modelling" and "Observing, Measuring and Modelling in Science"**.**

The *scientific method* is the way to *understand* the physical origin of a phenomenon. To understand is different from *believe* or simply *know*, 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 to *experiment* means to 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 the Science Course examples are presented in which the scientific reasoning is stimulated starting from relatively common and day-life phenomena.

Four topics have been chosen for the Science OOC: two general and two thematic.

- ✓ 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

The materials which have been produced are: presentation on general aspects, sheets of simple lab experiments, complete experimental paths and videos. For each topic, the following materials and activities have been prepared:

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

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

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

Traditional teaching is based on a «transmission» approach; the teacher, who is the owner of knowledge, transmits 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 idea 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.

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 opinions under scrutiny.

The Lab Teaching steps are:

- Design: the teacher identifies competences to be acquired and chooses contents, schedule, products to be realized, working methods, technologies.
- Introduction: the teacher poses one or more questions about the topic to learners and encourages them to carry on a first exploration of it, starting from their opinions, ideas, knowledge, however acquired.
- Exploration: the learners conduct a first research, in external environments (museums, libraries, universities, business, nature, etc.) or in the net.
- Assignment: the teachers asks learners to realize a «product», giving them hints, tools, materials, suggesting technologies, and explaining assessment criteria.
- Execution: learners do their research and realize their «product» working in team.
- Socialization: learners discuss among working groups and compare results, problems and solutions, procedures.
- Assessment by the teacher.
- Synthesis by the teachers and links to other topics and activities.

The learning environment offered to students is very important and the laboratorial teacher builds a learning environment that:

- Stimulates learners to build knowledge, rather than reproducing it.
- Confronts learners with «real» tasks.
- Confronts learners with multiple representations of reality (words, graphics, formulas, pictures, videos, etc).
- Encourages reflection and reasoning.
- Stimulates cooperation, confrontation, team working.

Believe, Know and Understanding are the three steps towards comprehension about a phenomenon

Our comprehension about a physical phenomenon could derive from three different approaches:

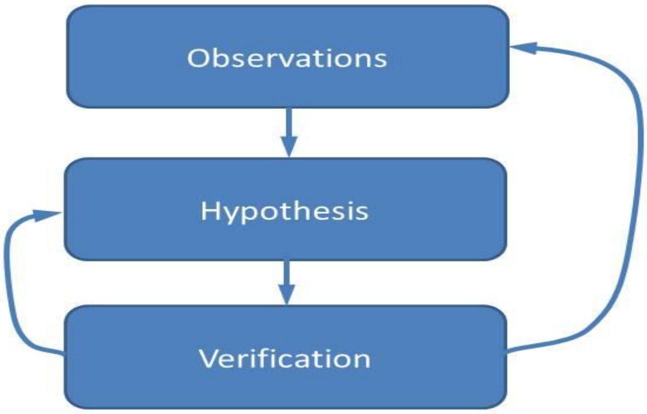
- to believe
- to know
- to understand

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

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.

Understanding is different from *believe* or simply *know:* 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, making hypothesis and verification in a continuous cycle. This is an always ongoing process with which science continually tests its laws, revises a theory, reviews its results.



In this process, *making hypothesis* represents the fascinating and creative part of the Science. Often this steps is skipped while we propose 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.

The materials and activities produced for the *Measuring and uncertainty* section are "The role of uncertainty" and "Error propagation: the Montecarlo method".
Uncertainty is an intrinsic factor measuring any physical quantity. 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. A sheet containing a simple measuring experiment has been prepared: measuring how tall a student is while standing and lying.

“Error propagation: the 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 simulate the effect of a statistical distribution. Here it is implemented using a spreadsheet.

In the section *Methods in Science: Modelling and data fitting* the following activities have been prepared:

- Refractive index of water
- Temperature gas expansion
- Parabolic fall
- Bacterial counting procedures M1
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Settimio Mobilio illustrates the Parabolic fall experiment in detail:

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**:

From the *Earth Science* section the “Seismo box” experiment is illustrated. It deals with Earthquakes, reproduced in a special box made of materials which are commonly used in everyday life.
Finally, from the *Energy in Science* section some other experiments are briefly illustrated: “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), “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), “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 how junk food can be used to update approach to calorimetric measurements and thermodynamic laws. The objective is determine the heat of combustion of prepackaged sweet or salty snacks using a calorimeter designed by students), “Biochemistry: Leaf At Work” (from where does the leaf take energy to survive and

grow up? The role of light and photosynthesis processes are experimentally investigated and understood).