A Web Site about Historic Experiments (HE)
The Galileo Free Fall Experiment
The Topics – The Structure

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ABSTRACT

Any modern curriculum has science literacy as one of its aims. In such a curriculum the study of the natural science should have a prominent place. We believe that history of science provides another way to the understudying of how science works. The presentation of Historic Experiments is a way to present the evolution of the ideas in Science. The Historic experiments like Galileo's Free Fall Experiment contributed to the establishment of the scientific theory for motions, led to the introduction the new concept of inertia and has influenced the evolution of the ideas in science and the society (Millar R., Osborne J., (eds). Beyond 2000)..

In this paper, we present our view of how such an experiment should be present on Internet so it serves as educational material in class, for the Secondary Educational level. Text from Galileo's book "The Two Sciences", references to the social conditions the period he was experimenting, animations, simulations of the relevant theories and work sheets are included. We think that this material will help the student:

a) to realize that scientific knowledge is always subject to modification

b) to understand that the gradual accumulation of knowledge over many centuries has led to the growth of science and technology of today and

c) to acquire a deeper understanding to the phenomenon itself, as well as, the way the scientist (Galileo) worked in trying to explain it.

In this way we believe that the student is engaged in the scientific process.

Keywords: Historic Experiments, Free fall, Free Fall Laws, Galileo

INTODUCTION

The idea of teaching in class elements from the History of Science and reproducing a number of simple Historic experiments is a way to help students learn about the nature of scientific inquiry and to encourage school teams in working as "researchers" and discover the way of discovering (AAAS, Historical perspectives: 1993),.. More specifically:

- Pupils get familiar with real problems and with the way the pioneer researchers solved them. Possible solutions can be subject of discussion in class. Since in the early years the experiments were done using simple devices, it is quite possible that some students will come up with realistic suggestions. For example, the problem Galileo was facing was how to measure time. Our students are surprised to hear this and are curious to learn how the problem was solved.
- The pupils get an idea of all the difficulties and contradictions around a revolutionary theory, like Galileo's Free fall theory. It is important to realise that it is not easy to understand the physical phenomena (not only to them, but to everybody); you must make a real effort and spend a lot of time in taking continuous measurements and improving the apparatus used. At a later stage the students will find out that the scientists often don't follow in their research the standard step of the scientific method as we teach them at the secondary level; their work includes the collection of phenomena of relevant evidence which in combination to logical assumptions and the intuition of the

researcher lead to the scientific hypothesis.

- Dealing with real problems, the students learn the concept of controlled variables; if two or more parameters vary in an experiment then you cannot have clear results from the experimental data. It is difficult, in this case, to correlate specific changes to the relevant magnitudes. One should be careful in designing an experiment and selecting the devices, to avoid such complications (AAAS, The nature of science: 1993).
- The students get aware that the results of a research might be different than the expected ones. New ideas are often the product of such situations and they lead to new research (*T. Kuhn,1962).*. In the options "The Determination" and "The Hypothesis" of the site, the students will find the first and the second hypothesis of Galileo about the falling objects.
- The determination of the researchers inspires young people; the example of brilliant men and women, who had to prove themselves, motivates them. Hard work in Science pays, maybe not with money or fame, but it gives a real pleasure to the person who becomes able to understand the mysteries of the Nature (Gil-Perer D. 1994).

Presenting Historical Experiments on the Internet has certain advantages:

- In a web site, detailed instructions can be given to school teams that want to reproduce a historic experiment, accompanied by simulations.
- It is possible to exchange ideas and present the work of teams who perform their version of the Historic Experiment (Π. Δημητριάδης: 2000, Stefan Aufenanger: 2000) .
- It serves the Science teacher by providing him/her with material tailored to the needs of the Science lesson. Each presentation can be given in both a short form and a detailed one, which cannot be done in a book. Most science teachers will limit themselves to examining the short option. For someone who is more deeply interested in a certain part (e.g. the historical events, or the detailed description of the experimental data) there is the possibility to find out more about it by reading the detailed description on the site.

THE TOPICS - THE STRUCTURE

Figure 1. The main menu

Having all the above in mind, we tried to create as an example a web site about Galileo Free Fall experiment, a historic experiment which has influenced the evolution of the ideas in science.

We tried to give to the web site the appropriate structure, so it covers both the technical features as well as the evolution of the ideas, the personality and the sociological impact of the HE. The content of the site is tailored to the standard steps of the Scientific Method. That is:

The Previous Theories and their incapability to explain the new data

The Hypothesis and its validation through the experiment

Step by Step: A description of the experiment; the declaration of the variables, the collection of the experimental data, the variable dependence in the mathematical model (Π. Δημητριάδης 2002).
The menu options represent the steps above trying to familiarize the user with the Scientific Method's steps.
Moreover, it allows the teacher and the student to find easily what he/she is interested in.
The text is divided in small parts; we tried to make it simple and clear. In each page there are static pictures, animation or simulation, with some degree of interactivity.
Worksheets varying in content and difficulty are included, in order to keep the attention the students and test them.
The topics in the web site are:

- The Importance (of the Experiment)
- The Personality (Galileo's personality)
- The Determination (of Galileo)
- Aristotle's Theory (the previous theory)
- Doubts… (about Aristotle's theory)
- Galileo's Doubts (about Aristotle's theory)
- The Hypothesis
- The Experiment

In the options "Doubts" and the "Hypothesis" a few sentences of the original texts of Galileo is included. That is because, even short parts or specific expressions, usually give away the spirit behind an innovating action. Each Option includes links to other sites and worksheets.

Doubts… (about Aristotle's theory)
We present the logical arguments and the mental tests against Aristotle's theory from the ancient years until the Renaissance in the form of text or simulations. Our objective is for the student to realize that the scientific theories are under constant testing and reassessment; sometimes they are proven wrong and they are overthrown. In the work sheets the school teams will be able to find simple instructions how to repeat the "doubting" experiments themselves and so to understand those arguments; simulations may help in this direction. Some of the activities in the work sheets try to deal with the misconceptions of the students like that "the heavier bodies fall faster" (NATO: 1989, Thorton R.Q 1999).

The Experiment

The Options "The Experiment" includes the following submenus:

- The Breakthrough
- The Steps
- The Formulae
- Simulation Models
- Modern Experiments

The Breakthrough

The page starts with the problems and difficulties Galileo faced in carrying out the experiment. The user is encouraged to try out to find solutions and then, using hyperlinks he/she can see the solutions given by Galileo.
There is, also, a description of the mental experiment of Galileo which led to the introduction of the concept of Inertia. In the simulation of the experiment a ball rolls (actually slides) down a slope, and then rolls up another slope and reaches the same height where it started; the user can change the angle of the second slope and finds out that, each time the ball reaches the same height. It is pointed out to the user that, in this case, there is no friction. In the simulation of the experiment where the friction is not zero they can find out that the height that the ball reaches at the end, depends on the friction value and decreases as the friction increases. In the work sheets the school teams are given instructions to repeat a variation of the experiment using simple material. They make one slope and by using different materials on the horizontal plane, they can find out that the horizontal distance traveled by the sliding bodies depend on the friction. Our objective is that the students get to understand the concept of the controlled variables (height, inclination); it is an attempt of dealing with multi - variable problems.

The Steps

The students can reproduce the experiment of Galileo following the instructions and pictures. They must have already discussed about the problems and the solutions. At this stage they are encouraged to try to redesign the experiment under their teacher's supervision using probably modern measuring devices. They should define the controlled variables.

The Formulae

The students are given the mathematical equations of the free fall and the ones applied at the experiment with the inclined plane. At a later stage we are going to add the process through which Galileo reached the Free Fall Laws. They should find out whether they can reach the same conclusions through the experiment. We avoid the geometrical approach of Galileo and focus on the concepts of the physical magnitudes like the velocity and the acceleration. The students should be encouraged to work with the relevant graphs and extract information from them (Mokros: 1987, Dimitriadis P.: 1999).

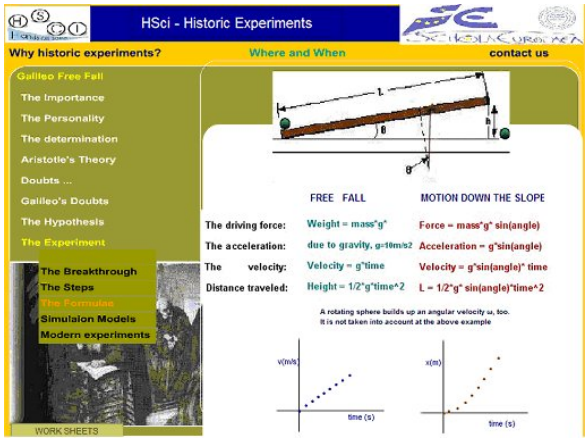

Figure 2. The Submenus

Simulation Models

In this part the students are encouraged to familiarize with the manipulation of the dependent and in depended variables, by using the options of the simulation programs.

The option "Modern Experiments" includes the submenu:

- Measurements (Static Pictures)
- Fall in the Air (Video)
- Free Fall (Video)
- Free Fall on the Moon (Video)
- Your Experiment (Instructions)

In the text, we tried to avoid long and tedious stories, as these will bore the students too quickly. The few students who would like to learn details can use the links to other sites.

An important part is the worksheets. Our experience is that the students are pleased to go through educational material on the Internet, but soon they become bored and lose attention. They must be encouraged through properly prepared questions to discover the satisfaction of observing "physical phenomena" (e.g. a video or simulation of a machine) and of controlling the simulated events by interacting with the programs. Some teachers make the mistake of thinking they can leave their students alone in front of the computer; we should have in mind, that students always need guidance and inspiration, also when they work with material on the Internet.

We tried to take care that the educational material is presented in a flexible form. It should for instance be possible to be presented in class by the teacher or to be worked out by teams of two or three students for one or two didactic periods.

We tried also to encourage the users throughout the site, to try the experiment themselves in real life, because this is the best way to learn.

THE PLAN, FURTHER

The web - site has to be improved, in some ways:

- The simulations should become more detailed and interactive
- The work sheets collection should increase
- The texts should become more attractive

- A hands on experiment will be included, a reproduction of the original with the use of modern measuring devices

Still, in this phase, we believe that the web site can be tested out in class. With the use of proper questionnaires, we hope to have a feedback next school year that will indicate if the use of such educational material can contribute to the objectives of the "Hands on Science" project.
Based on the remarks by teachers and students, we hope to be able to improve the content and the style of the site.

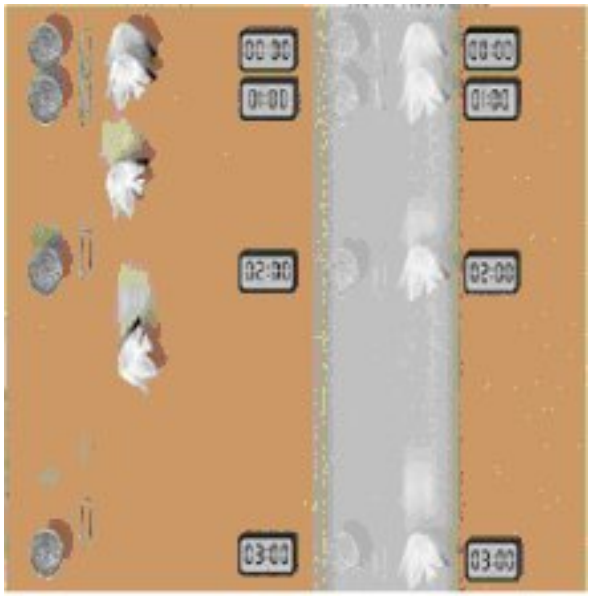

Figure 3. Free and non Free Fall Motion

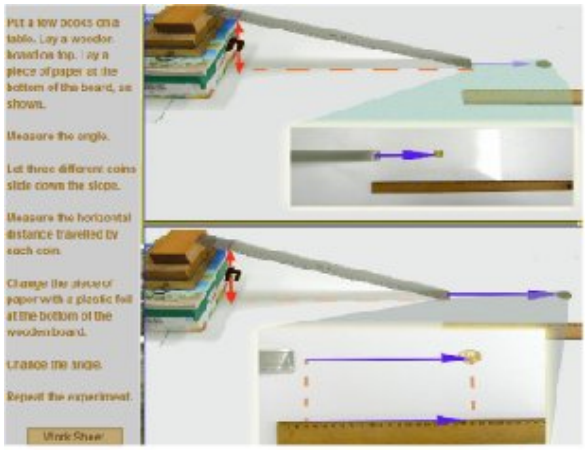

Figure 4. The worksheet

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