Hands-on Activities using Video Analysis of Motion with Low Cost Equipment - An Inquiring, Innovating and Utilitarian Proposal for the Hellenic Physics Curriculum

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Abstract. *The existent curriculum of Hellenic Physics' Lab has unfortunately been designed to run basically in a "Cookbook" style with a pre-specified course of actions for the pupils with the use of Microcomputer Based Labs (MBLs). Although MBL-effects upon student learning and conceptual development in undergraduate course of physics are un-doubtful, there are certain constraints in Hellenic schools, that eliminate those advantages.*

Our study aims to propose an innovative and utilitarian approach for the Hellenic Physics' Lab curriculum that will provide pupils with hands-on inquiring activities with the use of Video-Based Labs (VBLs).

Keywords. Low cost Video Analysis, Inquiringly evolving educational model, MBL, VBL

1. Introduction

Teaching High School's course of Physics and especially Physics' Lab in Greece, means following specific instructions. Both teacher and pupils receive an instructions' manual and they are obliged to follow a step-by-step guide through their preparation/experimentation/ and conclusion. The already mentioned manual includes a lab-sheet with empty boxes, tables and diagrams ready to be filled in. Firstly there is an introduction with the necessary equations needed for the sheet. The instruments that are going to be used are pre-specified and helpful figures are available for pupils in order to comprehend the given instructions. The most common equipment that are utilised in the Hellenic Physics' Lab are: the tape with the time stamp (Fig.1), a basic MBL consisted by two motion sensors connected with a timer (Fig.2) and rarely a distance sensor.

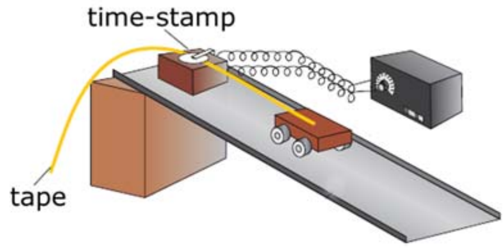

Figure 1

Unfortunately, most of the time there is only one pair of MBL's per lab which is usually broken. In most cases, due to malfunction, or even worse lack of equipment the teacher has no

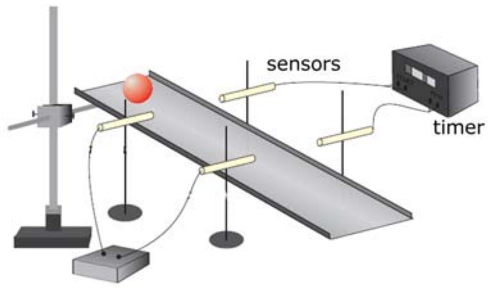

Figure 2

other option than to reproduce the experiment according to the given instructions and pupils can only take notes, as well as data and equations provided directly from the teacher that will afterwards use in order to fill in the Lab-sheet. All the above make the Physics' Lab boring for pupils as it deprives them from the feeling of discovering.

2. Our proposal

Although MBL-effects upon student learning and conceptual development in undergraduate course of physics are un-doubtful [1][2][3], as we already mentioned, certain constraints in Hellenic schools, eliminate those advantages.

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Our team is currently focused on developing a different way of teaching Physics' Lab with low cost instruments, which would be easy to use and would give pupils the opportunity to practice their solving problem skills and finally make physics significantly more interesting for them. The solution to all the above is VBL.

VBLs can be a powerful tool with similar advantages to MBLs [4][5] in improving pupils' comprehension of difficult and significant issues in physic, like graphs. The most significant advantage of VBLs is that the above can be achieved without any specialized hardware or instruments like sensors etc, but only with a low cost web camera and a computer.

Figure 3 – Low cost equipment

The main advantages of video analysis are:

- Video analysis programs are very helpful for elimination of various barriers, which are faced during the incorporation of real-world investigation into math-studies. Also, they are considered to be an economical solution for enrichment of investigations and applications of graphical, mathematical, and numerical representations with real world problems and data. [6], [7], [8]
- Video analysis technology is one of the few easily accessible methods in order to achieve quantitative studies for a big variety of physical phenomena, which are not too fast to be recorded at 30 frames per second. [4], [6], [7]
- Computer-based video analysis is also considered an easy method for pupils. In addition, as the latter need to judge and understand the video analysis process in order to scale the video frames or choose interesting points frame-by-frame they need to deal with boring process of data recording and to concentrate more on the physical phenomena under study. [6]
- A very important advantage of video-analysis software is the very low uncertainty of the measurements, compared to other kinds of measurements made in laboratories. In a video, pixels (short of picture element) are used by the video-analysis software to measure the distances, which are afterwards scaled in meters with the use of an object of known length found in the video. Considering that the dimensions of a standard digital image are 320x240 pixels, the uncertainties in position measurements are only about 1%. [6],
- Another important advantage of video analysis suites is their versatility. This feature allows every object, wherever it is located, to be recorded during its motion and then to be analyzed by the video analysis software. In addition, modern computer technology makes easy and feasible the video analysis of every motion, which has been videotaped and of every video format which is available. [4], [5], [6], [7], [9]
- There is a huge variety of video material showing physical phenomena that take place outside the science laboratory. A student can video analyze this material obtaining any useful information about the position of an object frame-by-frame and can also extract informative graphs of position, velocity, acceleration, force, impulse, and energy with just a click of the mouse button. [1], [6], [7]
- The video motion programs are usually free or inexpensive and can be incorporated into homework assignments or distance learning. The video material can be recorded in many settings like residence halls, classrooms or even outdoors using laptop computers and cameras. These videos are normally

very short, but long enough to show a phenomenon fully and can be analyzed with low effort. [6]

- The video analysis software, based on assigned masses of system elements, can be configured for the calculation of the center of mass of a system of objects, or a non-rigid object. [6],
- Video-analysis technology allows pupils to study two-dimensional motion, like side shot or projectiles, unlike probes and sensors (basic tools in MBL), which don't provide this feature. [5], [6], [7], [9]
- By using video-analysis in science laboratory, pupils can analyze and collect data from motions of more than one objects, which as a result allows the study of multiple objects that are in the same system. [5], [6], [9]
- Video analysis is a data collection technique that doesn't require equipment like: cumbersome wires, probes and sensors associated with MBLs. [5], [6], [9]
- Video analysis technology provides an opportunity for pupils to observe graphs and video of the event at the same time. [8], [12]
- Using video analysis, pupils can record objects and analyze motions, which take place in distances well beyond range of most motion sensors. [5]
- Finally, the fact that any captured digitized video can be copied to any computer that has a playback board, allows the school science laboratories to posses only one and not multiple copies of the necessary video equipment. This feature makes video analysis technology more affordable for the classroom. [5]

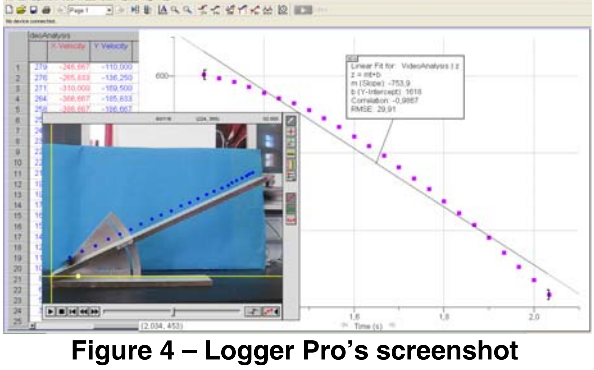

Figure 4 – Logger Pro's screenshot

For our study we used a five year old INTEL Celeron laptop and an external USB web-camera (MS Windows compatible) Fig.3. System requirements are not demanding of computational power. The software that was used consisted of two well-known suites for VBL: Logger Pro[10] Fig.4 which is a commercial packet and Tracker[11] Fig.5, a free cross-platform application. Both packets are user friendly and provide all the necessary tools for data analysis (graphs, equations e.t.c.)

3. Educational Model

Most physicists feel that lab courses are an essential part of teaching physics in school. Some have even gone as far as to state that all physics instructions should take place exclusively in the laboratory. Research conducted in order to determine the benefits of labs in teaching the course of physics, has consistently shown that labs which give pupils explicit instructions in a "cookbook" style have little value, particularly when it comes to addressing a problem-solving goal [12]. "Hands-on" experience is an efficient way in overcoming misconceptions. Solving a problem in the laboratory requires from pupils to make a chain of decisions based on their knowledge in physics. Wrong decisions based on wrong physics' understanding would lead to experimental problems that can be observed and corrected.

We herein present our view on how such experiments should be implemented in order to engage the pupils in the scientific process during lab-teaching, increase their ICT skills and provide all the advantages of Video Analysis with low cost equipment. Furthermore, as far as the educational approach is concerned, we suggest the scientific / educational by inquiry model [13][14], that includes the following steps:

- Trigger of interest
- Hypothesis expression
- Experiments
- Formulation of conclusions and proposals - recording
- Generalization - feedback – control.

3.1. The Model in-depth

<u>Before the lab</u>

The teacher imports the problem after having triggered his pupils' interest with an activity. (Step: Trigger of interest)

He describes the allocated equipment, and he assigns studies and a pre-lab test that needs to be answered by the pupils in order to allow them participation in the lab.

Studies are assigned to pupils split in groups and the latter need to cooperate with each other in order to collect information, formulate assumptions and design the experiment. (Step: Hypothesis expression)

At the lab

The teacher answers to questions and offers indications.

The pupils execute the experiment and collect data from measurements, (Step: Experiments)

The teacher answers to questions and offers indications once more.

The pupils analyze the measurements

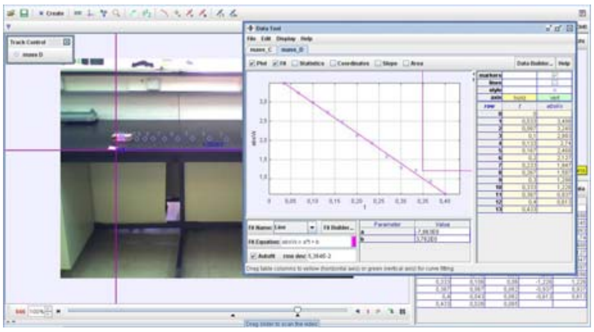

Figure 5 – Tracker's screenshot

After the lab

The pupils formulate conclusions. (Step: Formulation of conclusions and proposals - recording)

Finally, they publish the solution. (Step: Generalization - feedback – control.)

3.2. Video Analysis Procedure

Pupils, using a digital camera or a simple web camera videotape a physical phenomenon, which can not be too fast to be recorded. (usually video with 30 fps is preferred, but for slow phenomena video with even smaller frame rate can be used). After ~~the~~ recording, the digital camera must connect to a personal computer (desktop, laptop or netbook) with pre-installed a suitable video analysis software and the pupils after launching the software, insert the movie clip to the computer, for the process of analysis.

Pupils "mark" the location of the object in study in each frame of this movie clip by simply moving the mouse cursor over the object's location in the frame and "clicking." The program has the ability to advance (with every "click") the video clip automatically to the next frame, and even allows the pupils to predetermine whether they want to "mark" every single frame manually or every second, third etc skipping the rest of the frames to be automatically marked from the program itself, a feature which is particularly useful when analyzing lengthy video clips. As each frame is "marked," the vertical and horizontal positions of the object at that precise time are entered into a data table and are available to the pupils when needed. At the same time all the experimental data are automatically presented in suitable diagrams, visualizing the position and the velocity of the object horizontally and vertically, during the phenomenon.

After marking each of the desired video frames, pupils quickly and easily set as zero point (x=0, y=0) the lowest marked position of the object and use the meter stick in the video's background to convert coordinates values from pixels to meters. Since all the data and the graphs are scaled automatically according to the new measurement unit the pupils can now easily use the data, in order to calculate variables relevant to the physical phenomenon and its study. Fig.4,5

5. Results

This approach was followed in a set of four lab-exercises from the Hellenic Physics' Lab Curriculum. Those exercise were:

- Free fall
- Horizontal Projectile motion
- Measurement of kinetic friction coefficient
- Law of momentum conservation

In that first approach participants were students of Pedagogic Department P.E. and ~~the~~ pupils from the Greek team that will participate at the International Physics Olympiad – Croatia 2010. All those participants had similar characteristics to those of High School pupils.

Results from this process were the desired ones since pupils/students managed to practice their problem solving skills, learned how to design an experiment, gained an appreciation of the difficulty and joy of conducting and interpreting an experiment, learned how to use equipment, confronted their preconceptions about various phenomena and finally had fun by doing something more active than sitting back and listening. In other words pupils experienced what "real" scientists do.

Figure 6 – VBL Lab

5. Conclusions

Our study aims to propose an innovative and utilitarian approach for the Hellenic Physics' Lab curriculum that will provide pupils with hands-on inquiring activities with the use of Video-Based Labs (VBLs), in a way that pupils will find interesting that problem solving experience developing the same time their ICT abilities and revising their preconceptions about various physical phenomena.

The results of our work in the Science/Physics lab prove that VBL's can successfully replace the existent "cookbook" style-MBL Lab.

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