Non-face-to-face physics laboratory, an educational strategy

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Abstract. Under the health emergency implemented in Mexico City, due to pandemic caused by COVID19, and the measures to protect the population organized by the Secretaría de Salubridad and Federal Government, the face-to-face classes at all levels of education were suspended. This situation lasted for several months, so, in the case of the Universidad Autónoma Metropolitana, UAM, it was decided to continue conducting academic activities remotely. This decision brought an additional problem since some subjects taught in engineering careers cannot be implemented for the student to carry them forward at home. This is the case with physics labs. Situation that led to this educational research. The issue to solve is How can you teach Physics Lab in a non-in-person way? In this paper we describe how the objective was achieved, specifically in the Learning Teaching Unit, UEA, Laboratory of Rigid Body and Oscillations. Using Information and Communication Technologies together with the use of Video and Video Analysis Software, a working method could be implemented in which all the stages of experimental work were carried out. The results of the activities carried out at home by the students, communicated in the respective written reports, show that the proposed method for remote teaching of Laboratory of Physics is feasible and allows to carry out the process of non-face-to-face teaching at the higher education level.

1. Background
Several years ago, within the framework of the IV Ibero-American Workshop on the Teaching of Physics, IV TIBERO, held in 2007 in La Habana in Cuba, already considered the need to implement Remote Physics Laboratories. The main argument was the lack of equipment in the physics laboratories of the Schools and Universities of Third World nations and on the other hand the possibility of working in agreement with well-equipped universities of First World countries. Some ideas were raised, such as automating experiments with sophisticated equipment that could be handled remotely. Finally, nothing was realized, and the matter was pending.

On the other hand, the availability of Computerized Data Acquisition Systems with powerful electronic sensors to take data very quickly and the availability of software to process information and deliver, almost immediately, the results of the experiment, led the learning teaching process in the Physics Labs to another stage in the cognitive and attitudinal processes in students.

Now, the so-called National Period of Healthy Distance implemented by the Health Authority and the Federal and Local Governments, to prevent the spread of COVID 19 contagions, forced the discontinuation of non-essential face-to-face activities everywhere. This led to the impossibility of teaching in university classrooms and laboratories.

For this reason, the academic authorities of the UAM implemented the so-called Remote Teaching Emerging Program, PEER, to continue teaching, but in a non-face-to-face manner. This led to a process of uncertainty because most teachers are not enabled to work in this way and on the other hand a large percentage of students do not have computers or internet service in their homes.

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This meant that, in the case of the Division of Basic Sciences and Engineering at UAM Azcapotzalco, responsible for teaching 10 different Bachelor's degrees in Engineering, it had to offer to students a limited number of courses. Therefore, the UEA's Physics Laboratory, in the General Trunk of Subjects was a severe educational challenge.

This paper sets out the strategy implemented in the 20 I trimester to deliver the UEA Laboratory of the Rigid Body and Oscillations in a non-in-person form.

2. Elements in the experimental work
Along with theoretical research based on the analysis of publications and specialized books and computer simulation of a phenomenon on which a model has been built, experimental activity is very important in the process of investigating the behavior of phenomena for which we have little or no information.

Experimental work is not just to verify compliance with a law, nor to repeat known experiments. It is of fundamental importance for the discovery of unknown behaviors in nature, so the student must be trained properly to carry out the work in the Physics Laboratory [1].

In experimental work we must recognize the following elements:

- The definition of the theme of work
- Important variables and parameters
- The variables to be measured
- The experimental technique to use
- Equipment selection
- The experimental arrangement
- Data analysis or processing experimental information
- The results obtained
- The discussion of results
- The conclusion
- The written report or communication

All these items must be included in a remote Lab course.

2.1. Data taking
Traditionally, quantifying important variables in an experiment was a manual process, using conventional measuring instruments. However, when the phenomenon to be quantified is very fast it is almost impossible to perform measurements manually.

With the availability of electronic sensors, interfaces, software, computer programs and computers it is now possible to take up to 250,000 data per second from a phenomenon. The measured data are processed immediately and the required graphs and the equations that describe tendencies appear on the computer screen.

In order for the student to fully understand the processes carried out by the computer and the results shown, it is necessary to give them, special training since the cognitive processes, knowledge and skills required are different than for the conventional case. The student's attention must now be focused precisely on the interpretation of what the computer screen is showing. They should have an idea of what to get and compare with what they are getting [2].

3. Video recording in experimental work
On the other hand, if the Laboratory does not have the necessary sensors or computerized acquisition system, another way to obtain information about phenomena that happen very fast, or not, is by taking a video of the experiment. The video is then processed on the computer and separated into frames in which measurements can be made. The value of video analysis in physics education has been discussed, years ago, and is well established [3]-[5]. Also, commercial, and free educational video analysis software are readily available: Tracker 2011, Logger Pro 2011, Coach 6 2011, VideoPoint 2011, Alberti's Window Motion Visualizer DV 2011 [6].
4. The software Tracker
This software created by physlets.org, is open to use and is available for free. This software is very important to be able to perform the analysis of experimental data remotely, that is, from the home of the students. Tracker software is a video analysis tool and behavior model construction developed on the Open Source Physics Java framework [7],[8].

It feeds with the video of the experiment; it is programmed with the number of frames that the operator is interested in analyzing. It will track a point of the selected object in the frame. It will build the table of position, velocity, acceleration, and other data, as well as the time involved, in one or two-dimensional movements. It also delivers the respective graphs. And of course, it also provides the adjustment of the graph and behavioral equations.

That is, Tracker, once the variables to be measured are defined, process the information and allows to do with ease, the analysis of the data, what we call the processing of experimental information, being able to quickly obtain the results [9]-[11]. With this the student builds a model of observed phenomenon behavior.

5. The Laboratory of Rigid Body and Oscillations
This Learning Teaching Unit is taught in the so-called Common Trunk which forms the core of basic knowledge of Physics, Mathematics and Chemistry for the 10 degrees in engineering that are offered in the UAM Azcapotzalco.

The general objective of this Laboratory is to carry out activities focused on experimental analysis of the oscillating phenomena, simple and damped, that occur in various systems; the phenomena of combined rotation and translation of rigid bodies, as well as the case of one-dimensional collisions.

The theoretical framework under which experimental activities are analyzed includes:

- Simple harmonic movement.
- Harmonic movement damped.
- Analysis of the rotation of the Rigid Body by Newton's Second Law, translational and rotational, and by the principle of Energy Conservation.
- Principle of Linear Moment Conservation.
- Stationary Waves and Normal Vibration Modes.

5.1. The laboratory
Within the PEER, the way in which this subject was taught was:

- Through weekly videoconferences lasting three hours, in which the activities were:
  - Exposure by students of the Report or written communication of the experiment conducted the previous week at home.
  - Discussion and academic criticism of the presented document and suggestions for correction.
  - Approach and the application of the theoretical framework, by the Professor, of the next experiment to be carried out at home.

6. The educational strategy
The educational strategy consisted of:

- Students who had a Computer were asked to install the Java Software and Tracker Software. Students were asked to form four-pupil work teams, at least one of whom should have a computer.
- Each experiment was conducted in the house of one of them, based on the resources that the student had and according to the approach of the activity previously explained by the teacher.
- The student in charge of the experiment was asked to also take a video, which was taken with his cell phone camera. The student then sent the video, via email, to the colleague who had the computer and the indicated software. This student analyzed the video with the Tracker software to obtain the data tables, the graphs requested and sometimes the behavioral equations. By sharing this information with the other members of the team, they discussed the results, elaborated the findings and the final report. In other words, it was taken care that all stages of experimental work were carried out, although in different places.
6.1. Experiments conducted

- The experiments that could be done in the nine-week trimester were:
  - Simple Harmonic Oscillating Movement
  - Damped Harmonic Oscillating Movement
  - Seismic simulation
  - Normal vibration modes on a rope
  - Rigid Body Bearing
  - Newton's 2nd Law Analysis
  - Energy Conservation Analysis
  - Collisions and Linear Moment Conservation

7. Results

The students, in the oral exposure and in their written reports showed satisfactory compliance with all stages of experimental work. Although the experiments were conducted at home with the items they had at hand, not with professional equipment, the sequence of activities carried out allowed them a significative learning.

8. Conclusions

Relying on the video to capture the experimental information, in the Tracker software to analyze the video and in the Video Conferencing it was possible to implement a non-in-person course of Physics Laboratory, Laboratory of rigid body and oscillations.

The academic results obtained were favorable and the attitude of the students was very participative and satisfactory in engaging in an innovative work strategy.

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