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Optics@home: Active remote learning on geometrical and physical optics

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Summary. — Optics@home is a learning path developed under the Italian Project Piano Lauree Scientifiche in Physics at the University of Salento with the aim of involving high school students in experimental scientific laboratories. Due to the health emergency caused by the COVID-19 pandemic, the university laboratories were not accessible to students, so we were forced to modify and innovate our laboratory teaching methodologies. In detail, we proposed in-depth optics spacing from the geometrical to the physical one in remote teaching.

1. – Introduction

The project was conceived during the emergency situation due to the COVID-19 pandemic when school students could not visit the University Laboratories and involved a group of about 30 16/18-year-old students.

In this period of distance learning many students showed lack of motivation to learn and study, so we looked for strategies to catch their attention and involvement. We had to consider a new alternative and innovative didactic modality with the introduction of new methodologies through the diversification of the laboratory physics environments [1, 2]. The main goal was to stimulate students' curiosity, keep their interest alive and maintain their motivation. Indeed, one of the risks of remote teaching is that lessons are perceived as boring and not concrete.

We have selected five significant experiments for optics and designed five teaching units. Each lesson is devoted to a specific optical phenomenon which has been addressed by means of an intrinsically related process where theory, simulation and experiment have contributed to the comprehension of the physics laws.

The lesson units have been developed into two phases (fig. 1): the first one was in a synchronous way. In this first phase we presented the theoretical principles of the phenomena and described some experimental ideas which can be used to verify the related physics laws. We also performed experiments in the department laboratory and the school students followed them while staying at home in live streaming. At the end of

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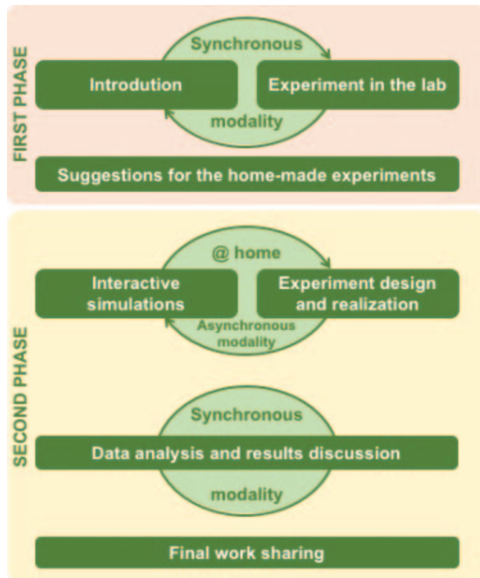

Fig. 1. – Description of the typical lesson phases.

this first phase we gave suggestions to students so that they could autonomously verify at home the laws that had been considered.

In the second phase, school students were involved in first person and the work was mainly developed at home (asynchronous modality). In the first step of this phase, students explored the phenomena through simulations. They were performed with applications such as PhET Interactive Simulations [3], which have been demonstrated to be powerful tools for achieving learning physics: clearly this does not mean that laboratories in presence may be replaced. In the second step students used their creativity to settle an experimental setup by employing simple equipment realized with common and easy to find materials. Moreover, they discovered that smartphones are a big resource since they can provide many sensors which can be used for interesting experiments. Sensors can be managed through opensource applications [4, 5].

The experimental setup has been designed and realized under the supervision of school teachers. Then students performed the experiments, and acquired and analyzed the collected data in small groups (remote cooperative learning). The obtained results were then collectively discussed in synchronous modality (second phase - third step).

In the end, experiences were presented and shared with the other students during a final Closing Day held remotely.

2. – Description of the units

In the following some details of each lesson unit are given.

Light refraction and Snell's law: after the experiment in the laboratory with a plexiglass half-cylinder, a goniometer and a diode laser to determine the limit angle, the setup was realized at home with a pointer laser and a transparent box, of regular shape, filled with a diffusing liquid (for example, water and coffee) in order to easily observe the laser

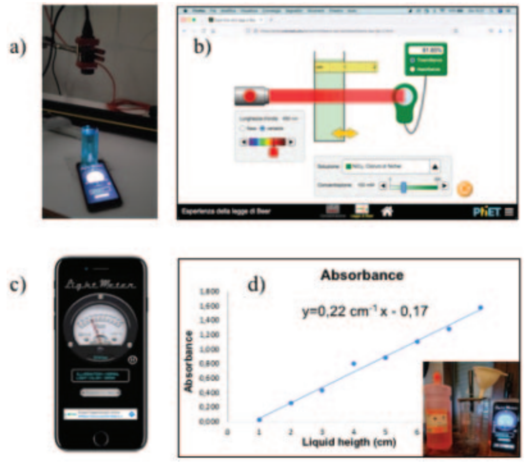

Fig. 2. – (a) Lambert-Beer law demonstration in the laboratory; (b) simulation with PhET; (c) light-meter application for the home-made experiment; (d) plot of the experimental data acquired in the experiment performed at home with simple materials (as shown in the inset).

beam path. The angle measurement was carried out with an Android application for smartphones (Angle). The law was also verified by means of simulations with PhET.

Lambert law: to study the light intensity dependence on the distance from the source (a commercial lamp) smartphones were used as light sensors (lux-meter) through the Light-meter application. After the sensor calibration, carried out in order to evaluate the background contribution, the intensity data have been recorded, plotted and fitted to find the relationship between intensity and distance.

Lambert-Beer law: by remotely following the experiment performed in the laboratory, school students learned the concept of transmission and absorption. Then they investigated this phenomenon through the simulation on PhET by changing both the optical properties of the transmitting medium and its thickness. In the end they built their own experimental apparatus. From the plotted experimental data analysis, students have deduced the absorption coefficient of the used liquid (fig. 2).

Light polarization and Malus' law: students realized their home-made optical bench to align the source (a pointer laser), the polarizers (lens from glasses for 3d vision fixed on a goniometer) and the detector (a smartphone sensor with lux-meter application). The experimental data were then compared with the theoretical ones.

Diffraction law: the law has been verified by analyzing the diffraction patterns of one or more slits from both simulations and remote laboratory experiments. At home, the students used different diffracting objects such as a small comb or a hair, of which they have measured the diameter.

The proposed project is an open-ended plan, which is suited for additional insights and methodological variations thanks to the versatile use of smartphone applications and simulations. Students, by discovering the potentialities of smartphones and by exploring their functions, can think of the possible different uses and develop new experiments and projects on their own.

Moreover, the use of smartphone technology allows school teachers to enlarge a single activity by encouraging students, through questions or suggestions, to speculate on the interpretation of the observed phenomena, to reflect on the obtained results and to make predictions.

The praise, involvement, enthusiasm and originality in creating the experimental setups shown by school students have been a confirmation of the efficacy of the proposed project. Indeed, students appreciated this project because in the experiments at home they were involved at every step, making decisions and thinking critically about their works. The obtained results confirm that challenging learning methods improve comprehension and interest.

3. – Conclusions

The rapid transition to remote teaching due to the pandemic has posed particular challenges for laboratory courses.

The proposed didactic path has been developed in the Action 4 of the PLS project in which school students play an active and independent role in setting up the experiment apparatus and in performing experiments. Nevertheless, other PLS actions have been taken into account, such as Action 1, related to university orientation and to a more conscious choice of the university courses, Action 5, related to students self-assessment and awareness of their own potentialities, and Action 6, devoted to school teacher training. Indeed, not only the students but also the school teachers have been actively and enthusiastically involved and have gained awareness that simple experiments can be proposed and realized also without the need for advanced instrumentation, well equipped laboratories and specialized technicians.

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