

# ONLINE PHYSICS LABORATORY FOR UNIVERSITY COURSES

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E-learning and video technologies provide new tools to learn the laws and phenomena of experimental sciences. This novel approach complements the theoretical classes not having practical sessions. The online Physics laboratory is our first project. It consists in video-mediated experiments on the elastic force and harmonic oscillations. The online video experiments allow the students to investigate the elastic phenomena by extracting, collecting and elaborating experimental data. The aim is to give to the students a practical example on how a real physics experiment is conducted. High-resolution videos permit to record a physical phenomenon in a digital form and the video elaboration allows to collect the data. This kind of experiments are "real": videos become a real scientific instrument of measure. Finally, to reproduce the collaborative environment of a laboratory, we organize an online collaborative experience, by a peer assessment of a work-task done by the students at the end of their work. At the same time, we intend to

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analyse the learning process of the students through their behaviour and their perception in using the online tools of the platform and during the peer assessment experience. This is to identify the optimal tools and the most effective e-learning for the online laboratories. Our results are quantified by the data extracted from the Moodle platform, by analysing the reports of the students, and by a survey done on the collaborative activities.

## 1 Introduction

For scientific courses with experimental laboratories at university level, e-learning seems to not give significant contributions to the learning of the experimental method. The efforts of the e-learning community have been focused on virtual realities to simulate the experimental environment and to conduct the experiments. Here we aim to demonstrate that e-learning and modern video capturing provide new tools to learn experimental sciences.

This novel approach has the objective to give to the students the possibility to participate to a practical example on how a real physics experiment is conducted, following the experimental method of physical sciences. This is particularly important in courses without practical sessions. At the same time, we intend to analyze the learning process of the students through their behavior in using the online tools of the platform. This is to identify the optimal tools and the most effective e-learning approach for the online laboratories.

In our online laboratories, we adopt the “problem solving”: an active learning in which students have to develop experimental and analytical skills rather than schematic knowledge. The students are required to create new problems, to generate new knowledge, to simulate and use the methods of the scientific research. This work is focused on the realization of online laboratories of Physics for the 1st year of the Bioscience and Biotechnology course of the University of Camerino (Italy), an international degree in English. The idea is to make the online laboratorial experience as much real as possible, including the collaborative aspects which are typical of a laboratory. This is now days doable thanks to high resolution video recordings of real experiments. The videos of the experiments have been realized in the Physics Division. In collaborations with the professors of the Physics courses, we have chosen one important topic of general Physics: the elastic force and the harmonic oscillations.

During the visualization of the videos of the experiment, the data have been extracted from the videos by the students in an interactive way and analyzed by them using the free software Gnuplot. The students had the possibility to repeat the visualizations of the videos many times, in order to extract the data and understand the experiment in a careful and complete way. The data have been then critically analyzed by the students in order to formulate the physical law describing the considered phenomenon. The results of their analysis has been

reported in a final document marked by the teachers. The output generated by the students (forum, discussions, feedbacks, quality of the reports) during the online experimental part has been analyzed to verify the validity of the online laboratories. Finally, to reproduce the collaborative environment of a laboratory, we have organized an online collaborative work, by requiring a peer assessment of an additional task done by the students at the end of their experimental work.

We have chosen a kind of collaborative activity that allows students to give and receive feedbacks on the assignment and to revise and improve (if necessary) the draft version before the final submission for the evaluation of the teacher. This is because previous research study has shown that performance is further enhanced when assessment procedures include feedback and opportunities for revision (Gibbs & Simpson, 2004).

Furthermore, the peer review process has the value to improve self-evaluation capacities and a better understanding of the main concepts. Students report that they experience a deeper understanding of the course material by examining the perspectives of their peers (Guilford, 2001).

In this paper, our results are quantified by the data extracted from the Moodle platform, by analyzing the reports, and by a survey on the students behavior and perception about the “Peer Assessment”. The extension of the online laboratories to other topics and their embedding in the Massive Open Online Courses (MOOCs) are reported in the conclusions.

## 2 State of the art

Main effort has been dedicated by the scientific community to the development of virtual laboratories, with a fundamental role played by multimedia and graphical animations with different levels of interaction (University of Camerino, n.d.; University of Colorado at Boulder, n.d.).

An important step forward in the improvement of the online laboratorial experience has been recently realized by “The OpenScience Laboratory” of the Open University (UK) (Open University UK, n.d.), in which the learning experience in using scientific data has been enhanced with respect to the standard virtual laboratories.

Many videos of experiments are available in YouTube (Online Colleges, n.d.) but they are not suitable to allow data collection and analysis, and no collaborative work or support of an e-learning platform have been integrated. Moreover, the integration of the video-experiments with the course objectives is lacking.

An important progress is the “Zaption” platform, which supports the learning process with videos (Stigler, Geller & Givvin, 2015). “Zaption” is able to take a video from a repository (as YouTube), adding interactive elements

to the video: slides, discussions, questions. This enhanced video is published online, allowing students and teachers to use collaborative and interactive tools.

The learning experience of the students is amplified with engagement, curiosity, interaction, feedback, motivation. From a pedagogical point of view, a guide to the production of educational videos has been recently discussed in Toci *et al.* (2015). We note that remote laboratories, online data collection, and experiment control is a reality in many research laboratories. Therefore it is important to translate this experience into the scientific university courses: this is one of the main objectives of our work.

Another objective here reported is to embed the collaborative experience in online laboratories. This is done by a peer assessment of a questionnaire on the main concepts of the online laboratory. Peer assessment can be valuable for formative assessment and as a part of learning (Landry, Jacobs & Newton, 2015). A properly designed peer assessment may provide useful feedback to the students, while improving their work.

### 3 Methods

*Participants.* This study was carried out with a group of 46 international students of the first year of degree course in Biosciences and Biotechnology of the University of Camerino. The participation in the online Physics laboratory was voluntary. Ten of these students left the activities after the first part. The analysis of the results is done for 46 students in the first part and for 36 students in the second part. The students have actively participated to the online activities and we have assigned up to 3 extra points for their work. Two professors and one Ph.D. student of Physics of the University of Camerino have prepared the teaching materials, the video experiments, and supported the online activities.

*Research methods and procedures.* The online activities of the Physics course consist of two parts: a first part in which the student works alone with online experiments and a second part of peer assessment, in which the students work online to evaluate the problems solved by other students. The research methods and procedures adopted in our work and below described have been summarized in a visual way in the conceptual map and flow of investigation shown in Figure 1.

Before starting the online laboratory, the students attended in the classroom three meetings of three hours each with the teacher and the tutor, to understand the contents, to discuss about the rubric for the peer assessment and the structure and objectives of the online Physics laboratory.

In the first part, the online laboratory of Physics is focused on the 5 video experiments on the elastic force generated by the deformation of different

springs and their harmonic oscillations. Each video experiment lasts on average 10 minutes for a total of 50 minutes.

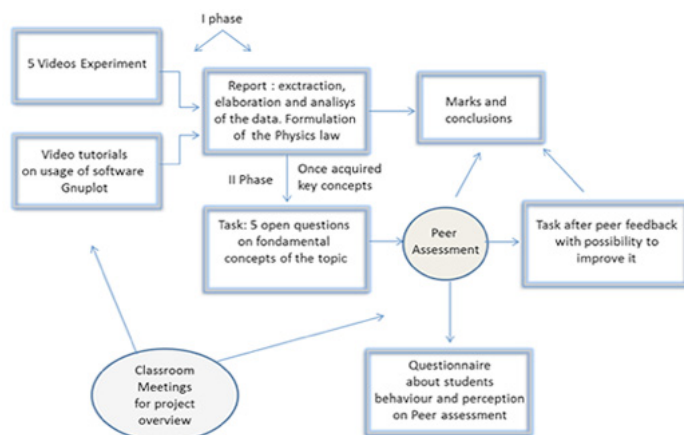


Fig. 1 - Conceptual map and flow of the investigation method adopted in this work.

The online video experiments allow the students to investigate the elastic phenomena by extracting and collecting experimental data, and by elaborating the data sets by using the free software Gnuplot in order to make a statistical fit of the data and to find the corresponding physical law. Two video tutorials are available in the platform to the students: *i*) how to install Gnuplot; *ii*) how to use Gnuplot to make a plot, prepare figures, and to make data fits. The videos on Gnuplot last a total of 15 minutes.

A forum in the platform is used for support. In the second part the students have been asked: (a) to solve a set of problems on the elastic force and harmonic oscillations individually and to upload the file with answers in the platform; (b) to participate to the peer assessment: the teacher assigns randomly and anonymously to the student, using the workshop tool of Moodle platform, the evaluation of the answers of two class mates (peers) and fills a rubric with his/her quantitative and qualitative judgement of the work of the peers (the rubric used for peers evaluation of the draft version of the task is shown in Figure 2); (c) the student receives by e-mail from the tutor the evaluation by two anonymous peers and will improve his/her own work on the basis of the assessment before uploading again in the platform their task for teachers evaluation.

The realization of both the first part (individual online laboratory) and the second part (peer assessment) is requested to get up to 3 extra points for the final Physics exam.

The project duration is four weeks: two weeks for the first part and two weeks for the second part. After submission of the final version of the task, all students have been asked to fill a multiple choice online questionnaire to explain what she/he did when improving their work using the feedbacks received by the peers. They have been also asked to report personal perceptions about the collaborative activity. The questionnaire included 12 questions that were ranked on a five point Likert scale. This questionnaire helped us in elaborating a detailed understanding of the processes behind the peer assessment.

*Data analysis.* Our results are quantified by the data extracted from the Moodle platform, by analyzing the reports of the students, and by a questionnaire survey on the collaborative activities. To establish the validity of (high-resolution) video as a real instrument of measure that allows the students to extract data and to understand the main concepts, we have analyzed: (i) the time spent in the platform by each student to visualize the videos; (ii) the results of the reports to verify the correctness of the extracted data. In addition, we have also evaluated the elaboration of the data and the formulations of the corresponding physical laws. The rubric of Figure 2 has been used by the students for the peer assessment activity to prepare their quantitative and qualitative feedbacks. Moreover, the same rubric, including the specification of the points, has been used by the teacher to evaluate and mark the assigned task before and after the peer assessment, in order to quantify the level of improvement applied by the students thanks to the peer suggestions. To study the behavior and the perception of the students about the peer assessment activity we have analyzed the answers to the final survey questionnaire containing twelve questions. The questions are reported in Figure 4, together with the analysis of the answers.

Rubric	Marks
Exercise 1	[25 points]
1. Is the elastic force law written and discussed in a correct and complete way ? /10	
2. Is the spring constant discussed in a correct and complete way ? /5	
3. Are the units of the spring constant correct ? /5	
4. Does the student discuss correctly the way to modify the value of the spring constant ? /5	
Exercise 2	[20 points]
5. Is the total force acting on the mass written and discussed in a correct and complete way ? /10	
6. Are the units of measurement used in this question correct ? /5	
7. Is the result found by the student correct ? /5	
Exercise 3	[15 points]
8. Is the ideal harmonic oscillator defined properly ? /10	
9. Are the approximations discussed in a correct way ? /5	
Exercise 4	[25 points]
10. Are the approximations discussed in a correct way ? /10	
11. Is the result found by the student for the period and the frequency of the oscillations correct ? /10	
12. Is the discussion of the last question on the consequences of considering a lighter mass correct ? /5	
Exercise 5	[15 points]
13. Is the result found by the student corresponding to the question (5a) correct ? /5	
14. Is the result found by the student corresponding to the question (5b) correct ? /5	
15. Is the result found by the student corresponding to the question (5c) correct ? /5	
Give your qualitative feedback writing what is well done, what could be improved and was done incorrectly.....	

Fig. 2 - Rubric used by the student to evaluate the draft versions of the peers.

## 4 Results and Discussions

*Results:* *i)* Realization of 5 videos of experiments on the elastic force and harmonic oscillations designed and conducted by the teacher of Physics. The presence of the teacher enhances the interest and the curiosity of the students, with an high level of attention to the videos (see Figure 3).

*ii)* Analysis on how students used the videos: Video experiment 1 - 114 views; video exp. 2 - 51 views; video exp. 3 - 43 views; video exp. 4 - 57 views; video exp. 5 - 69 views. Once the students get used with the data extraction from the first video, the subsequent ones were viewed less time. We noticed an increase in the number of views of the last video in which the different type of experiments required more attention. The time spent in visualizing the videos is also of interest: 6 students spent from 1 to 4 hours viewing the videos; 24 students spent between 5 to 9 hours; 6 students spent between 10 and 15 hours. In average, each student has spent 6 hours in visualizing the videos on the experiments and on the video tutorials for the software Gnuplot. Being the total time duration of the videos around 1 hour, we can conclude that the students needed to view the videos many times (6 times in average) to be confident on what they were extracting, understanding, and learning from the video material.

*iii)* Analysis of the reports of the students. We have marked the reports on the online laboratory and on the peer assessment, finding very satisfactory results. The marks of the 36 students have been: 24 students got the maximum score of 3; 12 students got the score 2; no one got 1 or 0. In particular, on the basis of the teacher evaluation of the reports of the online laboratory, we noticed that all the students were able to extract the experimental data by using the videos. The precise extraction of the experimental data has been demonstrated in the reports realized by the students by a detailed representation and analysis of the collected data in nice plots prepared by using the software Gnuplot. This is one of the most important result of our work, which will encourage the realization of new online laboratories for our University.

*iv)* From the survey on the peer assessment, we got an high level of interest and satisfaction by the students on this experience. The results of a multiple choice questionnaire with 12 questions filled by the students to understand their perception about the peer assessment experience are very positive. We report the details of the 12 questions and the corresponding answers of the students to the survey questionnaire in Figure 4. As an example of the questionnaire outcomes we have the following positive results: 25 students have revised the first draft of their exercise; 25 students have improved their final work; 27 students have improved their knowledge of the topic being an assessor and providing feedbacks; 24 students think that the peer-assessment is a valuable learning experience. A deeper analysis on the validity of the peer assessment



is in order at this point.

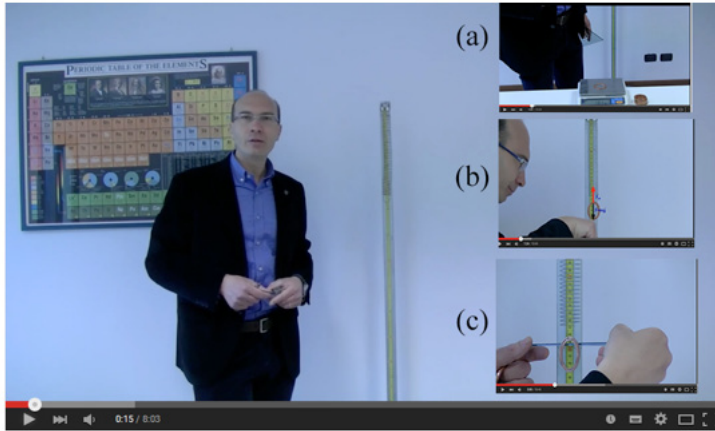


Fig. 3 - Screen shots of a typical video experiment to collect experimental data: (a) measure of the mass; (b) scheme of the force vectors; (c) measure of the spring deformation.

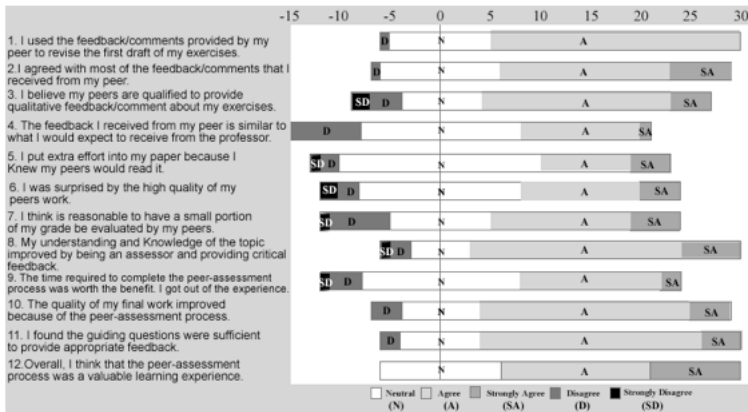


Fig. 4 - Responses to the final questionnaire about student behavior and perception on peer assessment.

On the basis of the positive answers to first question of the questionnaire (see Figure 4, Agreed), we have compared in a quantitative way the draft and the final version of the task document of the 25 students who responded that they have applied revisions to their documents after the peer assessment. In a future extension of the present work, we will analyze also the comparison of the students reporting a “Neutral” answer to the first question.



In Figure 5 we report on the vertical axis the assignment grade (maximum mark is 100) given by the teacher before and after the peer assessment activity for each of the 25 students here considered (student identification number is given on the horizontal axis), in order to validate the effectiveness of the peer assessment on the improvement of the task results. The mark of 60 is the minimum score to pass the task test. The results of Figure 5 are the following: 17 students have improved in some way or in a considerable way their assignment, but two students of them were in any case not able to improve enough their work to pass the task threshold of 60.

Two students obtained the maximum mark of 100 already for the draft document and hence they did not need a further improvement of their work. For them the feedback has been useful to confirm and validate their answers, while applying a few improvements in the presentation of their answers. Five students did not apply any significant changes on the basis of the feedbacks, even though two of them had already a very high mark of 98 and 95 respectively. Only one student over 25 introduced a mistake after revision on a specific question of the task, leading to a lower final mark with respect to the draft version; in any case both draft and final work of this student were well above the minimum threshold of 60.

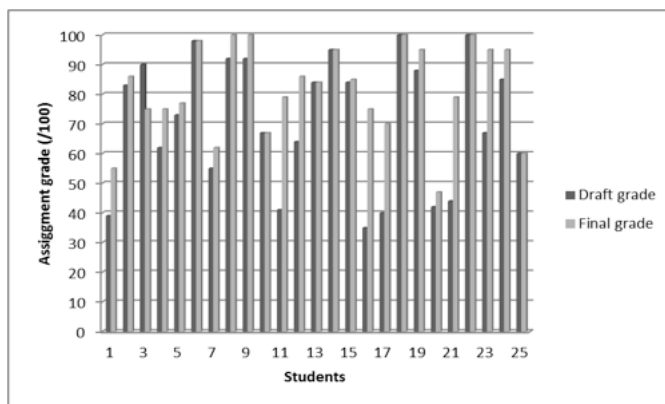


Fig. 5 - Comparison between teacher assignment grade on the draft and on the final version.

*Discussion:* The objective of this work is to verify the validity of the online laboratories, controlling the potential of the videos to engage students and to be able to extract experimental data in a clear and effective way, while embedding the collaborative experience. Videos of experiments permitted to record a physical phenomenon in a digital form and the video elaboration allows to

collect the data with a direct involvement of the students. The design of the videos made by the teacher focuses the attention of the students on important topics of the syllabus. The validity of the videos has been further demonstrated by the students' reports in which we observed that the collected data have been correctly extracted by the videos.

Regarding the peer assessment, it is now a validated method and here we confirm its validity in improving the knowledge of the students on the main concepts behind the online laboratory. We have compared the teacher grades before and after the feedbacks received during the peer assessment activity, finding a considerable increase in the average performance of the students in fulfilling the assigned task. The results of the satisfaction survey of the peer assessment indicate that it is a valuable activity, leading the students to a deeper thinking on their reports with improvement of the final result. These results strongly support the use of the peer review and the peer assessment as a profitable activity to complement our online laboratories. As a future development, we plan to complete the present analysis by studying the relationship between the change in the task grade from draft to final version and the number of comments requiring active improvements in the document provided by the student assessors during the peer assessment.

## Conclusions

Main results of the online video laboratories of Physics are the engagement of the students, the possibility of a real experimental experience conducted online, the extraction and elaboration of scientific data with the formulation of the physical laws, together with the usage of scientific software. Interestingly, the peer assessment of a task on the main concepts of the online laboratory gave to the students a new work experience and an original example of online collaboration. The quantitative and qualitative analysis of the positive, as well as negative features of the online laboratory here presented have permitted to establish the guidelines and the indicators of quality for future production of other online laboratories, having an enhanced experimental reality and collaborative work embedded in the online activities. In addition, online laboratories have the potential to become an asset for the MOOCs (Paleari *et al.* 2015) extending the production of MOOCs to scientific topics in which the experimental part and the hands on experience is of key importance.

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