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Teaching Physics at the time of the pandemic

M. SERIO

Dipartimento di Fisica, Università di Torino - Torino, Italy

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Summary. — The health emergency caused by the global COVID-19 pandemic has forced university teachers to deeply modify and innovate their teaching methodologies. We wondered how and how much these new teaching methods have worked, whether they have contributed efficiently to the preparation of students and which of these could be used in the future as support for those students having problems in attending lectures and exercises on site, such as working students, students with disabilities and students with special educational needs (BES), *i.e.*, characterised by stable or transitory difficulties requiring customised interventions. The survey presented here concerns, more specifically, the Physics Experiments I course, which in Italy is carried out during the first year of the Degree in Physics. The course involves laboratory exercises and, therefore, has significantly been modified by remote teaching.

1. – Introduction

In the spring of 2020, the health emergency caused by COVID-19 forced Italian universities to quickly find alternative solutions to frontal teaching for all the training activities conducted during the second half of the academic year.

Ramella and Rostan [1] conducted a national survey on teaching during the semester of the emergency. They interviewed a sample of 3398 university professors and researchers, who responded to a comprehensive online questionnaire. Their analysis showed that, throughout the national territory, the action of the universities in dealing with the problem was prompt (72% of teachers were able to activate remote teaching by 13th March) and useful in supporting the didactic activites (89% of teachers obtained support for the transition from frontal to remote teaching). The variation in teaching strategies prompted 67% of teachers to partly vary the contents and structure of the courses: the laboratory courses obviously were those that were most affected by these didactic variations for the unavailability and inaccessibility of equipment.

The author is part of the didactic team for the Physics Experiments I, which is carried out during the first year of the Degree in Physics. We work with first-year students, but,

above all, we have to set up laboratory work with students who do not have, on average, any experience of laboratory practice. A survey, conducted at the beginning of the course over the last three years, has shown that 10% to 15% of students have never attended a laboratory before and 45% to 48% have rarely done so. From 45% to 70% of the time they have only taken part in an experiment led by the teacher or technical staff. Therefore, the course is the first real opportunity for them to have a first-hand experience of the laboratory with the appropriate equipment and educational support of teachers, technicians and tutors. We, therefore, experienced a considerable degree of difficulty in our university setting in adapting the subject to online teaching just like 70% of university professors interviewed by Ramella and Rostan. Finally, it was in our interest to assess how much our educational effort has affected the preparation of students and what advantages/successful outcomes of the past year can be taken into consideration for this new academic year, which, sadly, seems to present the same pandemic aspects.

2. – What we have done

A large number of didactic activities was inplemented during the phases of lockdown, which have required the acquisition of software skills and their application, the development of technical skills, for example for the recording of video lessons, as well as a fair degree of imagination to find suitable materials to try to fill, at least in part, the lack of laboratory experience.

In addition to the Moodle platform, the University of Turin (Italy) has made available the following support activities for the various departments:

- Cisco Webex (software for synchronous video lessons, meetings, student consulting, exams, including online degree examination);
- Kaltura Capture (software for the production of video and multimedia content, directly accessible from Moodle);
- Technical support for e-learning activities, operational suggestions, and information materials, and
- Webinar cycle Teaching and learning: strategies for distance learning, held by experienced colleagues of the University

The teacher staff of the Physics Experiments I course reorganised the course and materials made available accordingly. Table I shows the teaching methods used.

Teachers reported that, compared to the previous pre-COVID-19 years, the organisation of the course required a more significant effort and a tremendous amount of time spent, in line with what was found at a national level. In particular, the increased burden involved the revision of the slides, the recording of the lessons with the related technical problems, the preparation of the laboratory data sets and the in-depth material and, last but not least, the management and conduction of the exams online. Ramella and Rostan reported that for 70% of professors the time needed to prepare a remote lesson has increased, 73% had to increase the time spent for examinations, 66% of professors affirmed that the evaluation of the students learning degree by remote teaching required a significant organisational effort.

A future working point concerns a part of the didactic material made available, which students have little used. This material needs implementation strategies different from those elaborated in the last academic year, poorly structured, and partly influenced by

TABLE I. – *Teaching methods used in the Physics Experiments I course (first year, Degree in Physics).*

Theoretical lessons	Laboratory and computer practice exercises
Previous years of video recordings	Synchronous lessons (Webex)
Synchronous lessons (Webex)	Slides and video commentary (Kaltura)
Asynchronous lessons (Kaltura)	Laboratory worksheet
Slides with audio commentary (Kaltura)	Self-assessment test
Research slides, textbook, exercises, materials	Python Notebooks for statistical analysis
Students reception (WebEx)	Interactive Simulation (PhET, Colorado)
	Assistance and consultation for data analysis (WebEx)

haste. In particular, we have to rethink the role of didactic material during training and preparation of exams. This will lead to a redefinition of how it should be used by students and how the teacher verifies this use.

Finally, the students seem to have followed online lessons and exercises with a frequency similar to that recorded in the classroom in the past years. As will be seen later, the degree of the exams is similar to those of previous years.

3. – What students think

In a survey, conducted by a group of young researchers from several Italian universities, over 16 thousand university students responded to an online questionnaire during the months of May–July 2020 concerning their teaching experience in remote (Monteduto and Nanetti [2]). Although remote teaching was considered less stimulating than frontal teaching, students judged distance learning as being "more than comforting". According to the transversal opinion of the interviewees, what was most missed during the period of lockdown was living the university not only as an institution but also as a community.

In June, with the help of the tutors, we submitted to Physics students (both those attending a Bachelor and a Master's degree) an *ad hoc* questionnaire, in addition to the questionnaire already prepared by the University for the student's more general assessment, which must be completed by all students in order to register for the exam sessions. We were able to obtain feedback only from a relatively low number (about a third) of students attending both the Bachelor and Master's degree. The low number of responses could partly be justified by the fact that the students had to fill out more questionnaires for all courses than normal. However, we can assume that the students who responded were perhaps also the most interested and, therefore, were more willing to collaborate by giving answers and comments.

Overall results were reasonably encouraging. Concerning the video-recorded lessons, we observed a slight preference for asynchronous (49.3%), compared to synchronous (39%) lessons, in contrast to what was reported by the University survey. More in general, students from the various faculties preferred a didactic method that was similar to what they were most accustomed to, *i.e.*, face-to-face lessons. Another countertrend result is the preference for videos that fully address the subject, even if with a longer duration, rather than 15–20 minute video-pills, as advised by the University's experts in

training webinars.

The presence of the teacher in the video did not appear to be strictly necessary, even if both professors and students complained about the lack of possibility of interaction. In the survey of Ramella and Rostan, 75% of the teachers interviewed complained about the reduced possibility of interaction with students, considering it a critical drawback of distance teaching. A result that emerged, both at a national and local level, was that, by remote teaching, university professors were forced to a more static and academic teaching due to distance compared to frontal teaching, which instead was more dialogical, interactive and innovative. Unfortunately, remote teaching often involved a drastic reduction of more innovative experiences. Teaching was simplified, returning to the traditional transmissive model (in which the student essentially has a passive role), although enriched by the discussion with students. We were also forced to simplify the way of conducting the examination. Frontal examination, in general, allows more affluent and more articulate verification modalities; remote sessions, instead, greatly simplified the way exams were conducted.

All the available material was found and used without considerable difficulty, but students pointed out problems with the phase of download (28%) and connection to the network (40%). These technical problems also created flaws on the sessions of online examinations, which were more tiring and even longer than those in presence. The conditions of internet access, the difficulty in getting and using ICTs, the socioeconomic circumstances as well as the influence of the home environment were the main factors affecting the continuity and effectiveness of remote studies, as has been demonstrated by a number studies concerning the effect of the digital divide (in addition to other factors) on the results of distance learning. See only as an example: Abuhammad [3], Adnan and Anwar [4], Alea *et al.* [5], Bao [6], Gabaldón-Estevan and Vela-Cerdá [7], Lassoued *et al.* [8], Sofritti and Orazi [9], Souza *et al.* [10].

Finally, the open discussion forums on the Moodle platform and the consultancy meetings via Webex were considered very useful by the students.

The analysis moved on to verify the answers of the students relative to the Physics Experiments I course. Concerning the theoretical lessons, at the beginning of the lockdown phase, students used slides and video recordings, which had been prepared in previous years, by different teachers and by applying a different time schedule (the calendar was organised in two semesters in this academic year in contrast to three trimesters of the previous academic years). Subsequently, as soon as the technical support of Kaltura Capture and Webex was made available by the University during the second lockdown phase, professors recorded synchronous lessons (for course A) and slides commented with implementations by tablet (OpenBoard software) for calculations and demonstrations (for course B). As shown in fig. 1, the students judged the theoretical lessons by assigning the score "useful" and "very useful" to the material and teaching methods provided during the first (video recordings and slides) and second (synchronous video lessons) lockdown phase. As depicted by the figure, the scores were opposite during the two phases with a higher percentage of students judging the classes as "very useful" during the second lockdown phase than during the first lockdown phase. More specifically, during the second lockdown phase, the teaching methods were considered "useful" and "very useful" by a higher percentage of students (88%) than during the first phase (79–84%).

Concerning the material provided for an in-depth analysis and the textbook (fig. 2), the percentage of students assigning the score "useful" and "very useful" was slightly lower (below 80%). Negative answers (not very useful, not useful at all, not used) oscillated between 10% and 20%. We believe that students sometimes felt over-

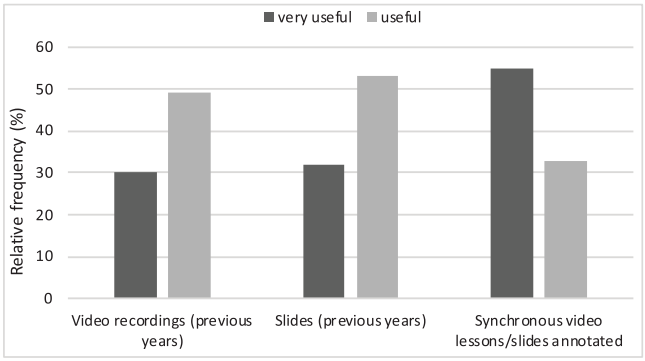

Fig. 1. – Students' judgment for the theoretical lessons during the two phases of lockdown: the first two classes are relative to the beginning of lockdown, the last one to the remaining period.

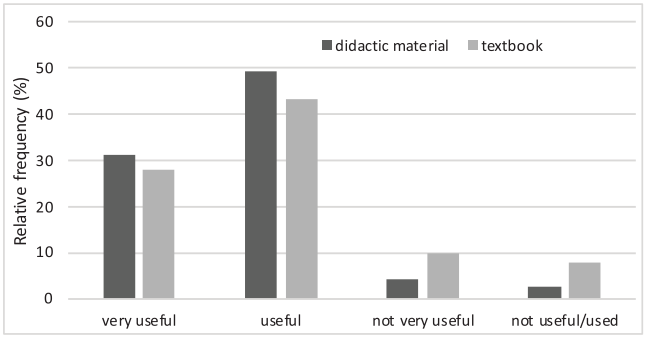

Fig. 2. – Students' judgement of the didactic materials and textbook for an in-depth analysis.

whelmed by the material available and therefore had more difficulty in discriminating and selecting what was more or less useful, giving priority to the video lessons in their preparation.

For the practical work and laboratory exercises, unfortunately, the COVID standards did not allow students to directly measure their data in relation to the practical experience in the laboratory: they were forced to analyse the data sets recorded by their colleagues in previous years. The teachers prepared a series of video lessons with some shooting in the laboratory, associated with interactive simulations, which were estrapolated from the Physics Education Technology Project (PhET) website, in relation to the topics of the experiments, self-assessment tests with multiple-choice questions concerning measurement procedures and instrumental features as well as worksheets and Python notebooks for data analysis. The students had to draw up laboratory reports in number and modalities that were quite similar to the past and the judgment expressed by the teachers did not reveal any particular criticality. The video lessons designed for the presentation of laboratory exercises were judged effective by 80% of students (fig. 3). However, the difficulty of describing the operating characteristics of the tools used or the execution of the exercise through a video certainly weighed on the percentage (just under 10%) that did not consider them useful.

Among the teaching methods provided, almost all (about 90% of the students) ap-

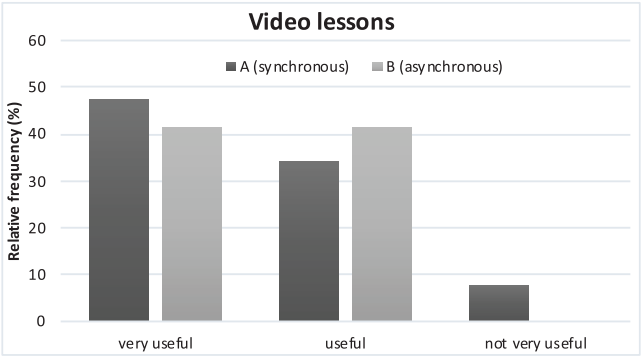

Fig. 3. – Students' judgement of the video lessons on the laboratory experiments: the two courses A and B made a different choice of the time mode of teaching (*i.e.*, synchronous and asynchronous).

preciated the consultations in small groups, replacing the tutoring in the computer classroom, and the Python notebooks for some parts of the statistical analysis. Figure 4 shows the percentage of judgment for these two modalities.

In contrast, self-assessment tests and interactive-computer simulations from the PhET website were judged useful only by 20–40% of students. Most importantly, a quarter of

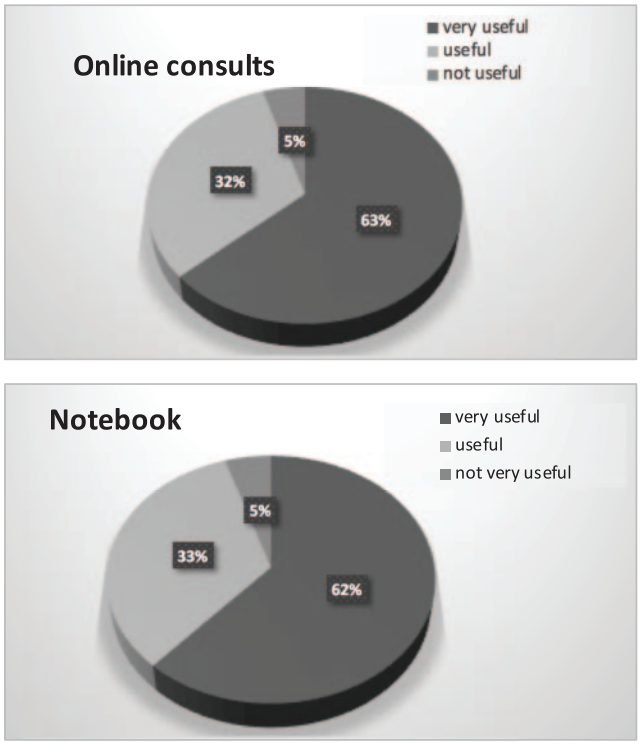

Fig. 4. – Students' judgement of online consults and the Python notebook.

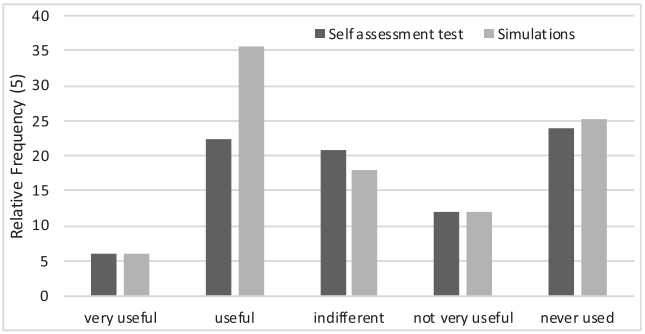

Fig. 5. – Students' judgement of the self-assessment tests on the experiments and computer-interactive simulations by PhET.

the students answering the survey admitted to have not used this kind of material at all (fig. 5). There were certainly neither punctual indications on how to use the material nor an on-going verification of its use.

This is the main didactic point to work on for the future. PhET programmes are specifically designed to engage students in active learning and provide a rich environment in which they can construct a robust conceptual understanding of physics through exploration (Wieman *et al.* [11]). We prepared a worksheet in which the interactive simulation was described and the change of any control to support every kind of simulation was suggested. The result consisted in an immediate animated response of the visual representation, which turned to be useful to help students in discovering the cause-and-effect relations of the variation in the physical parameters. There is no doubt that these simulations cannot reproduce what students practically perform in the laboratory, both as instrumentation used and as measurement procedures. However, the simulations offered the opportunity to explore "what happens if", partly compensating the impossibility of working with the real laboratory equipment. Their possible use in the future requires to better define specific learning goals and to monitor students' activities. Wieman and collaborators [12] highlighted that it is important to not "over-guide" sim use: with a guidance that was too explicit and structured, students were found to explore and learn less.

In the previous years students immediately compiled the self-assessment tests before entering the laboratory to carry out the practical experience. Therefore, they performed a quick review of the explanations obtained during the lessons, which had been conducted maybe only a few weeks earlier, because of the shifts, for the high number of students attending the course. This year, however, the aim was to reflect on the peculiarites of the practical experience to better analyse the data through distance learning. The teacher counselling via WebEx likely proved to be more accurate and useful.

To evaluate the results of the didactic methods we considered two data. The first was the % of withdrawals in the term. Withdrawals were students who stopped attending the course, but not necessarily dropped out of the course. The percentages recorded at the end of the examination sessions was 13% and 10% for course A and course B, respectively, and was only 1–2 percentage points higher than in the previous years so that the data was in line with the past, showing that remote teaching proved to be successful.

The second data was the exam grades. Figure 6 shows the averages of the evaluations of the two courses in the academic years 2018/19 and 2019/2020: the error bar

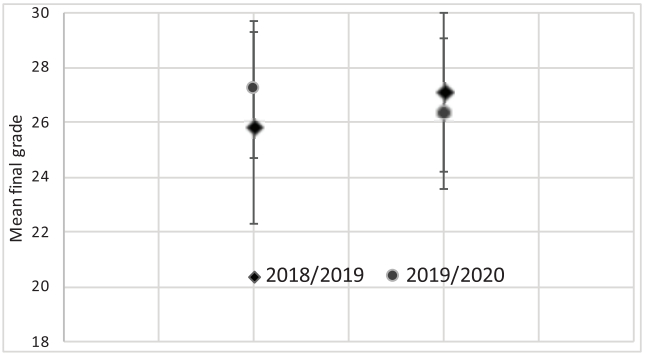

Fig. 6. – Mean examination grade for courses A and B over the two last academic years. The error bar represents 68% confidence interval.

represents the 68% confidence interval. These results indicate that students were able to use online tools to achieve a satisfactory degree of learning concerning the ability to analyse experimental data.

4. – Conclusion

Teaching during the spring semester with the issue of the COVID-19 global pandemic forced professors and universities, perhaps for the first time in many years, to pose questions about teaching, its aims and its modalities. Moreover, the experience of these months has shed light on the relationship between teaching and the new digital technologies. There is a need to avoid the risk that, far from transforming educational processes, the technologies and tools most frequently used in institutional learning environments can be used to replicate or reinforce teacher-led didactic practices (Kirkwood [13]). New teaching strategies can free frontal lessons of routine parts and facilitate learning autonomy and a greater collaboration among students. As reported by Ramella and Rostan 57% of the teachers interviewed were shown to be available for mixed teaching because they believe that this modality can improve the learning of the single disciplines, allowing to differentiate the modalities of interaction with the teacher. Furthermore, over 65% of teachers believe that distance learning would facilitate specific categories of students (working students, students with specific learning disabilities, economically weaker students) widening the audience of potential beneficiaries of university education (as continuing adult education) and making it more inclusive.

Returning to the initial research question relating to our course: what and how can we use what has been developed in this period of alternative teaching? The answer is, in fact, that the proposed material is valid but must be defined more precisely, with targeted instructions and monitoring of use. To this end, a possible evaluation of the student on the use he/she makes of the materials provided should be explored. For example, we can assign the design of an experiment worksheet or simulation sheets. We can also encourage the student to identify other simulations on physics topics from laboratory experiments. Finally, concerning self-assessment tests on laboratory experiments, we can think of assigning more effective closed questions to facilitate students who cannot follow the laboratory experience.

In conclusion, crises often represent opportunities, because they stimulate creative responses and trigger generative mechanisms, which allow us to undertake different paths

from the past. Moreover, the pandemic crisis has highlighted the crucial importance of teaching, one of the university missions, which is often taken for granted and neglected. It is, therefore, essential to enhance and improve what was created and developed in this period. There is still much to learn about the actual educational contribution that technology can make: the change in the means through which university teaching takes place, but, above all, the way in which university teachers teach and students learn (Price and Kirkwood [14]).

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