

Article

COVID-19 Outbreak: Insights about Teaching Tasks in a Chemical Engineering Laboratory

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Abstract: Apart from the evident tragedy that the COVID-19 outbreak has meant regarding both personal and economic costs, the normal functioning of the academic year has been drastically altered at all educational levels. Regarding Spain, the state of alert implemented by the government from mid-March to June has affected traditional face-to-face sessions at universities, as they were forbidden and replaced by online lessons. The aim of this work was to explain our own experience during the COVID-19 outbreak in a chemical engineering laboratory at the University of Extremadura, concerning the university teaching and the final degree project follow-up, whose method of teaching was active and participatory, based on constructivism and focused on the student as the center of the learning process. Thus, the confinement affected both the teachers and students differently, depending on the degree of completion of their main tasks and their previous skills with computing and virtual tools, among other factors. The existence of an operating virtual campus and an online library has made the transition to total e-learning and telework easier for teachers and students.

Keywords: graduate education/research; chemical engineering; bioenergetics; biotechnology; student/career counseling

1. Introduction

The so-called COVID-19 disease derived from the SARS-CoV-2 virus has caused the infection and death of thousands of people around the world. The uncertainty about the wide range of symptoms associated to this virus, the high risk of infection and the lack of a specific treatment up to now [1] have brought up a situation where most countries were not prepared and could not anticipate the consequences associated with the sudden cut of any professional practices. Consequently, during the spread of the virus in 2020 and until an effective treatment or vaccine is found, the main ways to avoid or reduce its effect are by complying with hygiene standards and social distancing measures [2,3]. These measures have strongly affected any interpersonal activity, including education at all levels, as students and teachers in many cases have avoided face-to-face sessions during this period [4,5]. Nevertheless, and due to the vital role of education in society, education has not stopped and has had to adapt to these changes, mainly resorting to e-learning when possible. In this sense, e-learning can be considered as a way of learning conducted via electronic media, mainly on the internet, used by both teachers and students. In the case of universities, there are some recent studies where the authors pointed out the increase in e-learning activities in Italy, which was especially affected by the COVID-19 outbreak [6]. The context of the University of Extremadura (concerning the implementation of e-learning and the interdiction of attending classes), in Spain, could have been similar, possibly observing the same trend (as discussed in the following section). Studies carried out by other authors point out the quick adaptation to e-learning by university lecturers and administrators in Germany contributed to the possible implementation of highly digitalized hybrid campuses [7]. Nevertheless,

this adaptation or transition should take into account many aspects. For instance, the digital skills of both teachers and students (in order to adapt the didactic contents to these new challenges), the design of e-learning courses, and their workload and interactivity, among others need to be considered [8–10]. Consequently, there are some signs that facing this difficult situation in the right way could imply the definitive implementation of telework and e-learning, at least at different levels. By telework (or teleworking) we mean the practice of working from home by using mainly information and communication technologies. In this work, this term and "e-learning can be used interchangeably when it comes to teacher tasks carried out at home, except for global work processes (including administrative tasks, for instance), where telework is preferred. In the case of students, the term e-learning will be exclusively used in this paper.

Although there are convincing reasons (such as family reconciliation, money or energy saving and mitigation of pollution) for the implementation of e-learning and telework, this implementation had been a slow transitional process, until their use was necessary due to the COVID-19 spread [11]. The effort to shift to this way of managing teaching staff, from preparing materials to designing suitable evaluation strategies, passing through the development of skills in using particular software, has to imply a permanent implementation of e-learning, not only to solve a temporary problem during a confinement. It can help traditional face to face teaching at the same time that it helps students in complex situations like this one; the benefits to the earth are too much to just ignore them.

The aim of this work was to expose our own experience during the coronavirus outbreak in the Chemical Engineering and Physical-Chemistry department of the University of Extremadura, in Spain, from the beginning of the state of alert established by the government to the subsequent stages for a return to a relative normality, as explained in Figure 1.

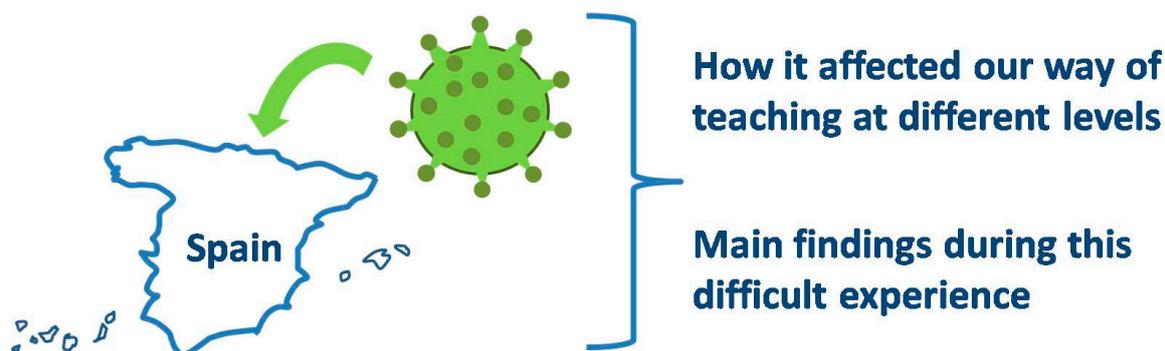


Figure 1. A graphical abstract of this work.

We believe that the lessons learned can serve to improve both teachers and students' achievements in the future.

Consequently, the following questions will be answered:

- How did the steps taken at national and regional level affect the normal functioning of our laboratory?
- What steps could we take in our laboratory to dampen the impact of the coronavirus outbreak on our staff and students?
- How were the final degree projects (FDP) carried out during this crisis?
- What were the main findings related to e-learning, FDP and communication between teachers and students derived from this crisis?

2. Context

In order to understand and have a general idea about the situation that took place in our university and the subsequent development of the events, some general data are provided in this section to

assess the reaction of the different entities implied (more or less directly) in the normal functioning of our laboratory.

Thus, after its spread through many countries, starting with China, South Korea, Japan, Iran and Italy, among others, the coronavirus outbreak in Spain took place at the end of winter. The main events that took place during this period are summarized in Figure 2.

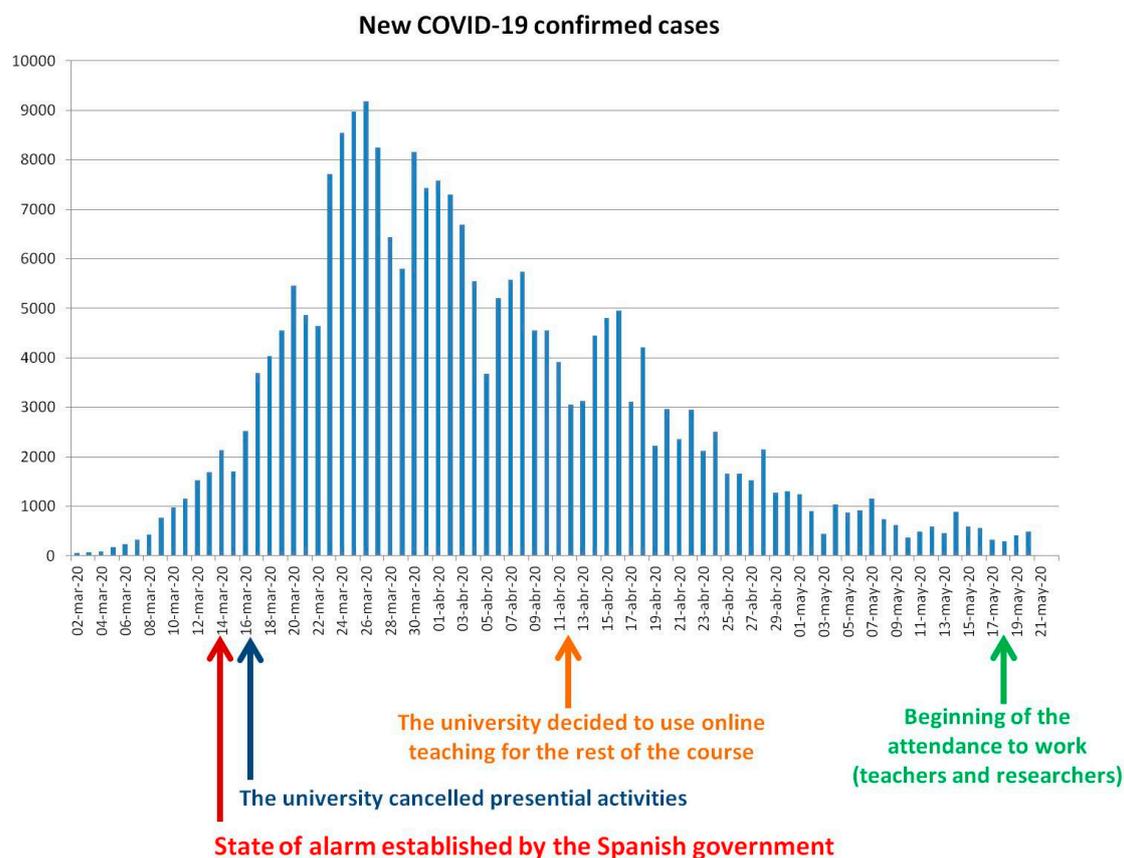


Figure 2. Main events during the COVID-19 outbreak affecting the functioning of University of Extremadura.

According to the data provided by the Spanish government [12], we can locate the beginning of the coronavirus outbreak in Spain in early March 2020, establishing the state of alarm (which implied restrictions in movements, and the normal development in commercial or professional activities, among other steps) in mid-March [13]. From then on, most companies, agencies and public administrations reacted immediately to this event, adapting their normal functioning to these circumstances. Thus, the main steps taken by the University of Extremadura were the following [14]:

- To cancel in-class activities, replacing it by e-learning, for the rest of the 2019–2020 course.
- To provide further training to teachers and students for e-learning adaptation.
- To postpone the exam periods of the second semester.
- To prepare and adapt workplaces for on-site work for teachers and researchers.

In order to avoid massive infections, the university cancelled in-class activities and on-site work (except for exceptional cases) immediately after the establishment of the state of alert. This way, the use of e-learning was promoted, at least provisionally (depending on the evolution of the outbreak). Finally, and according to the infection data (see Figure 2), the university decided to continue with e-learning until the end of the course. The tools available under these circumstances for teachers and students can be seen in Table 1.

Table 1. Main tools provided to teachers and students during the e-learning period.

Tool	Description	Reference
Virtual campus	Access to some online courses, notes, academic record, etc.	Virtual campus, University of Extremadura [15]
Online library	Access to main scientific journals	Library service [16]
Guides for teachers and students	Videos and tutorials about the use of virtual campus and online library	Webpage, University of Extremadura [17,18]

As a consequence, there was a considerable increase in the number of visitors to the virtual campus website [15] since the total transition to e-learning was carried out in mid-March. A way to assess this increase in the virtual campus activity was by checking the evolution of the Alexa Rank of its webpage, which is an index of the popularity of a webpage according to several parameters, such as the number of visitors. Consequently, as can be seen in Figure 3, the Alexa Rank [19] of this website improved up to 29,380 in July 2020, which was the period with the highest activity because of the exam periods (see Figure 4). It should be noted how the Alexa Rank was significantly worse in the same period last year (July 2019, with an Alexa Rank at around 45,000), which proved that the coronavirus outbreak and the subsequent state of alert provoked an increase in the use of this website. As expected, the same behavior was observed by other authors in Italy under similar circumstances [6].

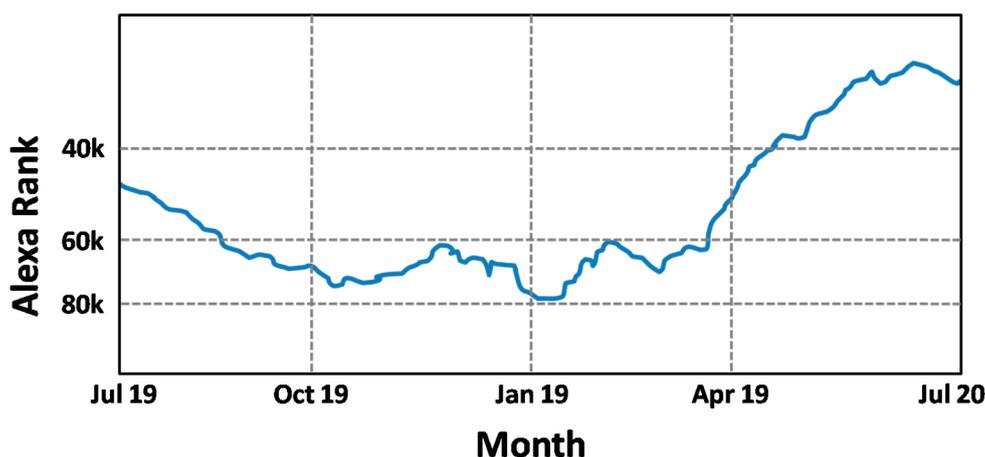


Figure 3. Alexa Rank evolution in the last year for the virtual campus site of University of Extremadura.

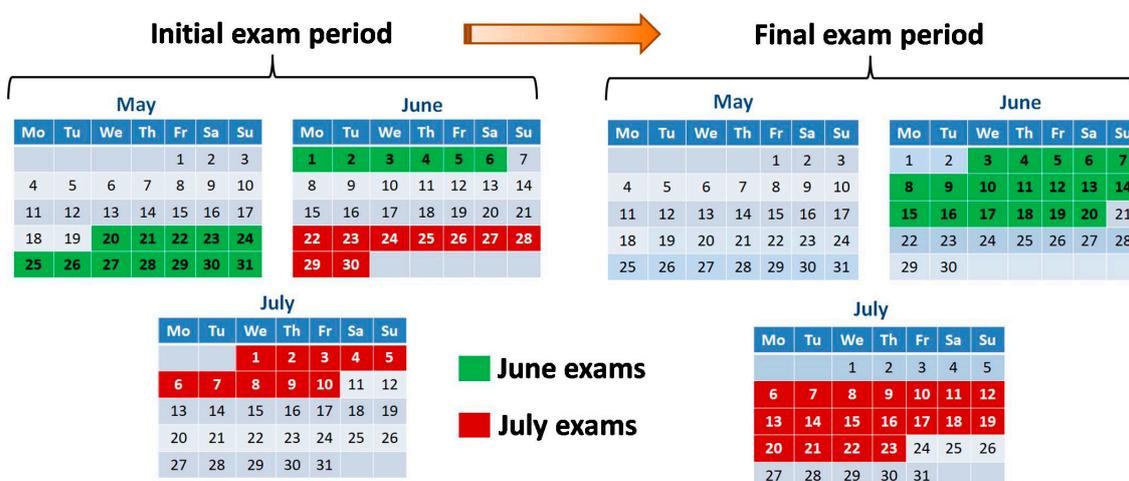


Figure 4. Main academic calendar changes for the second semester.

Some of these tools were already available, such as the virtual campus and the online library, which made the transition to total e-learning easier and less traumatic. However, and due to the recent and massive use of them, some guides were provided in order to make the adaptation to e-learning easier. Gradually, the university provided licenses on specific software (such as Zoom, Webex, Skype or Teams) to facilitate the management of online sessions, group meetings, etc. by teachers and researchers. Although this initiative was very convenient, many teachers did not have suitable computers at home to implement these tools and could not use them or had to buy the equipment.

Moreover, teachers were suggested to increase the number of continuous evaluation activities, in view of the uncertainty about the possibility of making the exam at the centers, and in consequence, they had to redistribute the weight of each evaluation activity on the final mark in the agendas. In order to promote the adaptation to these tools, there was a delay in the exam periods, as shown in Figure 4. Thus, in order to finish the course and to avoid an overlap with the following activities, these periods were delayed for only two weeks. We have to point out that the final degree project (FDP) defense is mainly included in the July exam period. Consequently, and taking into account that the main steps taken at a national level started in mid-March, there was not enough time to delay these periods if they wanted the following course to start normally (in September).

Concerning other issues such as quality control during this period, similar tests followed in the virtual campus were applied for the different subjects taught, and there were meetings with worker unions for health promotion during the confinement and the return to work.

Finally, from the 18th of May, the teaching and research staff could start the on-site work (especially for research and administrative tasks, not for teaching) with some restrictions and promoting telework as much as possible, after a previous disinfection of all facilities and the provision of some personal protective equipment such as masks. However, student attendance (except for some administrative or exceptional tasks) was forbidden for the rest of the course, and therefore our own experience about teaching from the coronavirus outbreak was through e-learning. Obviously, these measures did not only affect the time schedules but also the way of planning the public exposition of the work.

This was especially detrimental for teachers with low experience with ICT (information and communication technologies), who had to face a situation in which they felt insecure; this, in turn, brought up frustration in some cases. All teachers did their duty according to their previous training and motivation to learn, and a diverse range of options was found.

For the development of this study, the main results obtained in this study were based on anonymous surveys, specifically designed for teachers of our department and students, including the main data observed in the figures and tables (see the following section).

3. Our Own Experience

3.1. Methods of Teaching, Educational Tasks and Teaching Staff

The method of teaching used in our laboratory (both for theoretical and practical activities, including the final degree project) is active and participatory, where the student is the heart of the learning process, whereas the teacher provides educational guidance to the students. Thus, constructivism was applied in these cases, with the student carrying out tasks in order to “build” new knowledge that is based in familiar information (obtained in previous courses, mainly). Finally, in order to check the evolution of the student, at least three partial exams (which reduced the content of the final exam, if the student passes them) were carried out, including theoretical and practical exercises.

The main educational tasks carried out in the laboratory of biofuels in the Chemical Engineering and Physical-Chemistry Department are related to chemical and technical engineering for university students at all levels, including final degree projects (FDPs) as the final stage of advanced students before obtaining the university degree. Moreover, there is a special focus on scientific dissemination

for all audiences (from pupils to professionals), explaining the foundations of biofuels, as explained elsewhere [20].

Table 2 shows the main characteristics of the subjects covered. Regarding the subjects, they were taught in two quarters at most, with two to three weekly lessons (taking 50 min each), including laboratory lessons in most cases.

Table 2. Kind of education provided to students.

Kind of Education	Field	Students
Subject	Chemical and technical engineering	All levels
Final degree project	Biofuel and bio-compound production	Advanced students
Scientific dissemination	Biofuel foundations	All audiences

Concerning e-learning, the method of teaching used was based on the following key points:

- Implementation of e-learning, including training for teachers and students when necessary.
- The learning process was based on constructivism, an educational culture where learning implies a reconstruction process of information, and new information is related to the previous knowledge of the student.
- The role of the teacher was to support the learning process of the student, with the latter having the ultimate responsibility in this process.
- In this case, apart from other resources such as books, presentations or notes, the internet was the main source of information, based mainly on the virtual campus and the digital library.
- Online courses were created and published, implying the collaboration of teachers and a multidisciplinary team including designers, programmers and educational experts, among others.
- The main tool used was the virtual campus, where e-learning and mentoring were integrated, implying an interactive and flexible environment.
- On this website, carrying out individual and group works was possible for students, and the implementation of courses was suitable for both teachers and students.
- On the virtual campus there were other useful tools, such as a “notice board” for main events of the course (including the exam period), teaching materials (easily printable) and a discussion forum in order to facilitate the communication between students and teachers.
- The duration and structure of contents (including partial exams) of the subjects implemented in the virtual campus did not significantly change compared to the original courses.

The general and main concern for teachers and students about the complete implementation of e-learning was the sudden development of the events (at all levels, from national regulations to the subsequent steps taken by the university) and the little room for maneuver, especially regarding exam and presentation preparation. Nevertheless, the adaptation to e-learning was not the same for teachers and students, mainly depending on their own circumstances. Moreover, the communication between teachers and students had pros and cons.

Concerning teachers, we could classify them in three main levels (Table 3).

Table 3. Main characteristics of the teaching staff in our department.

Teaching Profile	Age	Level	Characteristics
A	Around 30	Assistant university teacher	Novel teachers (Skilled at the use of online teaching software, edition of videos, etc.).
B	40–60	Full university teacher	Used to the management of the virtual campus, including launching activities.
C	Over 60	Professors	Before COVID-19 outbreak, used the virtual campus mainly to upload documents.

Thus, two main factors affected the performance of teaching: the degree of completion of the subject and the familiarity with e-learning techniques.

This way, for the degree of completion of the subject, there were teachers who only gave lessons in the first semester, and only had to face exams in the case some students did not pass their corresponding tests. On the other hand, within the second semester, there were also teachers who had enough time to give their lessons, with the completion of the exam left. However, these represented a small minority of cases. Most teachers had to re-adapt their lessons to e-learning, as they were giving classes when the coronavirus outbreak took place.

For familiarity with e-learning, professors (Table 3, profile C) were clearly affected by this drastic change, as they were used to face-to-face lessons, whereas assistant and full university teachers (A and B, respectively) carried out this transition more easily. Indeed, the latter had already used, more or less frequently, the e-learning platform before this new situation. Consequently, professors tended to create short presentations (like those used in face-to-face lessons) with an explanatory text, whereas the other teachers could use other methods, like videoconferences combined with presentations. Nevertheless, all subjects were successfully completed, although sometimes teachers and students had to use their own resources to solve some computer problems. Regarding the exams, these were completed online. For this purpose, most teachers used the virtual campus site, where they asked the students to submit some theoretical and practical exercises. The most interesting and distinguishing characteristics (compared to in-person examinations) were the following:

- The online identification of the student was required to make sure that they were doing the exam.
- Teachers preferred to weigh logic instead of memory. Thus, practical exercises had an important role in final examinations, in order to avoid “copy and paste” solutions for the students.
- Instead of using a global test time, each exercise (or set of exercises) had a specific time for its completion. Moreover, the times were specifically chosen for each exercise, in order to avoid extra-time that could be used by the student to resort to ITC (information and communication technologies) to solve the tests.

3.2. Final Degree Project Mentoring

Concerning our experience as mentors of final degree project (FDP) students, we took some steps two weeks in advance, regarding a possible confinement by the government and according to the events taking place in neighboring countries such as Italy, including the following:

- We increased the working pace, in order to carry out as many experiments as possible.
- When, in some cases, we realized that all the planned experiments could not be carried out properly, we modified and reduced the experimental work as much as possible, so that our FDP students could have enough data to prepare their FDP defense at home.
- We encouraged our students to install the computer software required to carry out their FDP comfortably.
- We established an online communication with all our FDP students, to continue online mentoring.

The drastic steps carried out had a clear explanation: the low oxidative stability of biodiesel and biolubricant samples. As explained in previous works, the main raw material used in our laboratory is vegetable oil, whose fatty acid profile determines the quality and characteristics of the biofuels and bioproducts obtained from it. As a consequence, the content of oleic acid and linoleic acid makes the subsequent compounds generated by transesterification (that is, methyl oleate and linoleate, among other more complex esters) unstable during storage. This could be explained by the molecular structure of these compounds (Figure 5), whose double bounds are “weak points” to generate free radicals if they react with oxygen, changing some properties of the bioproducts, such as viscosity and flash point [21–23].

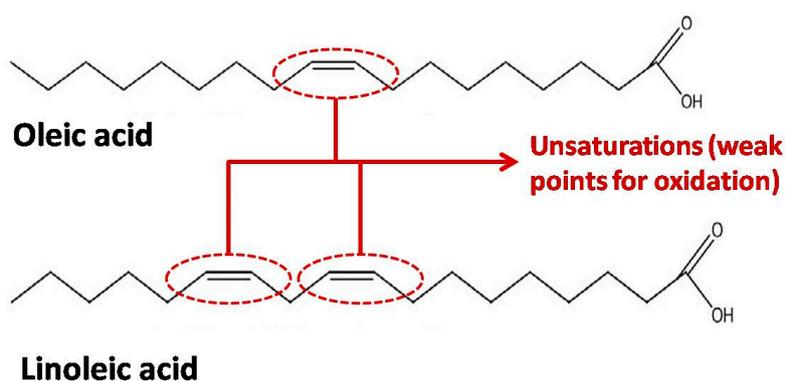


Figure 5. Simplified molecular structure of some fatty acids found in the vegetable oils usually utilized in our laboratory.

As a conclusion, every department should take into account the particularities of the final degree projects carried out, paying special attention to the nature of their experimental design (in this case, the instability of the samples treated) and including the availability of mentors and students, in order to interrupt in a proper way the experimental process of the FDP due to difficult situations like a state of alert.

According to our reasoning, it is important to try to classify the students into different groups, to understand the main trends observed, depending on their degree of completion of the project and paying attention to the experimental development. Figure 6 shows the main steps to be carried out during the FDP process in our laboratory.

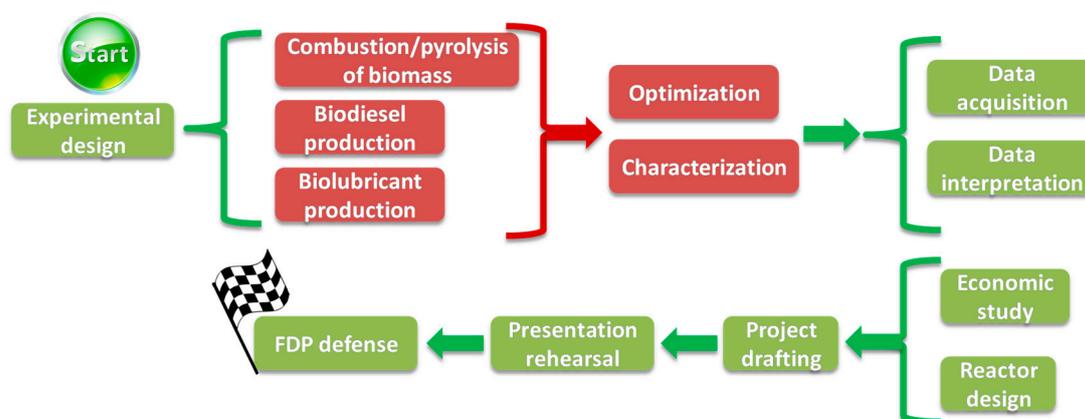


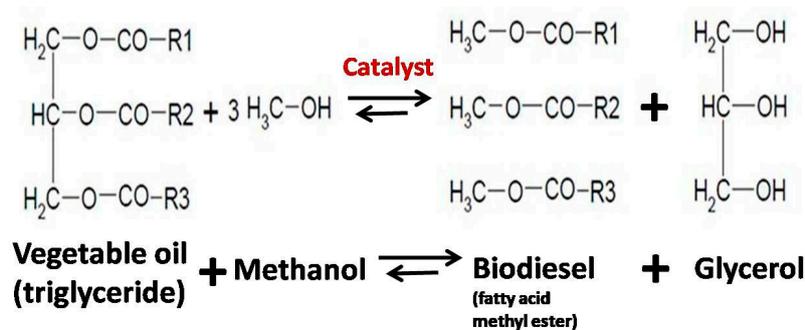
Figure 6. Main steps for the completion of a final degree project in our department. Steps that are mandatory to be done in the laboratory are shown in red. Steps that can be done by e-learning are shown in green.

Thus, the specific tasks carried out in our laboratory are included in Table 4. Most of these tasks were considerably influenced by the state of oxidation of the sample (that is, the vegetable oil). That was the reason why all these tasks needed to be done before the confinement. Otherwise, the results after this absence in the laboratory would have been completely different, as the properties of the vegetable oil would have changed (for the worse).

Table 4. Specific tasks carried out in person in the biofuel laboratory.

Step	Task
Combustion/pyrolysis of biomass Biodiesel and biolubricant production	Combustion/pyrolysis in a fluidized bed reactor Production through transesterification (see Figure 6)
Optimization	Optimization of the main parameters of the chemical reaction (temperature, catalyst, time, vacuum, etc.) in order to obtain the highest yield of a bioproduct
Characterization	Gas chromatography, IR, mass spectroscopy, UV/visible spectrum, viscosity, density, cold filter plugging point, flash and combustion points, surface analysis, etc.

In the same way, if the nature of the vegetable oil changed during storage (as it would have happened during the confinement), the chemical reaction to produce biodiesel or biolubricants (that is, transesterification, as it can be seen in Figure 7), and the subsequent production of the main bioproducts that are studied in our final degree projects would be altered, showing unacceptable results.

**Figure 7.** Transesterification reaction to produce biodiesel (fatty acid methyl esters).

As be seen in Figure 6, all the FDPs were focused on combustion or pyrolysis and biodiesel or biolubricant production, carrying out all the experimental procedure (Figure 6, in red) in our laboratories. Thus, according to Table 5, three different kinds of students were found, with their corresponding characteristics according to the degree of completion of their tasks, just before the temporary closure of our university (and, consequently, our laboratory):

Table 5. Different final degree project (FDP) student profiles before the coronavirus outbreak in Spain.

Student Profile	Experimental (Percentage of Completion, %)	FDP (Percentage of Completion, %)	Pending Subjects	Number of Students
A	100	0–20	0–1	2
B	50	0	3–5	2
C	10	0	3–5	3

As a consequence, we had to face different scenarios, and the students had to accomplish the FDP with some pending subjects, depending on the capacity of the student (although it is always advisable to have as much free time as possible to focus on the FDP). According to the table, only the students with their experimental part completed (that is, A students) were capable of advancing their FDP report during the confinement. This was due to two main factors: first, they had all their experimental data available to work (carrying out all the pending tasks in green in Figure 5) and second, they did not have many pending subjects to study. Consequently, they could increase their percentage of completion up to 100% during the coronavirus outbreak, being able to defend their FDP in June. However, B and C students, mainly due to the considerable number of pending subjects and the subsequent lack of time (because they had to adapt to virtual lessons), and on account of the scarcity of experimental data, did not advance in their FDP, calling off their planned FDP defense in June. Spinning in a vicious

circle, those students with more load of work due to pending subjects also left behind the FDP, because passing their exams was a priority, and tried to communicate with the teachers too late. On their side, teachers had less time to supervise their projects at the end of the period because of their teaching duties (mainly evaluation activities at the end) and had to make a big effort to refocus these works because of the lack of experimental contents. Moreover, and for the reasons already discussed, their defense will be delayed for months, as their raw material to carry out the experiments was oxidized, thus having to wait for fresh vegetable oils extracted from seeds that have to be collected.

3.3. Communication between Teachers and Students

Finally, we wanted to point out a particularity related to e-learning lessons and mentoring, that is, that the communication between teachers and students during this period has drastically changed.

The most preferred way of communication between teachers and students was the use of e-mails along with the campus virtual site. For an immediate and effective communication, a schedule (similar to the one established for personal meetings) was chosen, although it could be more flexible depending on the “emergency” of the student requirements taking into account these exceptional circumstances, even allowing for other ways of communications such as phone calls or instant messaging services.

Ironically enough for a period where most people were confined at home, a lack of communication was observed between teachers and students in their different modalities. Figure 8 shows the main reasons why this lack of communication took place, in our opinion.

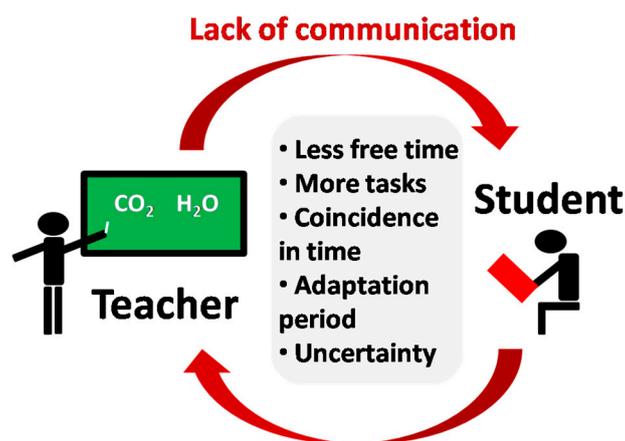


Figure 8. Main causes of lack of communication between teachers and students.

As explained in this figure, both teachers and students underwent (in greater or lesser degree) the following disadvantages:

- Less free time: Most teachers and students had family commitments, especially concerning children, which could not be solved at schools.
- More tasks: Many teachers are equally researchers, and during this period their tasks increased (for instance, there was an increase of peer-review activity, as many researchers used this period to submit pending research works).
- Coincidence in time: Due to the particularities of people (especially family commitments), they could work in the evening, at night, etc., not adapting to the schedule of other teachers/students who depended on their feedback.
- Adaptation period: Both teachers and students had to adapt to this new situation, by resorting to webinars or tutorials, in order to get used to the e-learning platforms.
- Uncertainty: Especially for students. Apart from the global uncertainty, which can cause cases of anxiety, depression and stress, as other authors have pointed out [24–26], the exam period extension could also cause demotivation.

Finally, during this period we were updating the prevention plan of the laboratory [27] for the following course, as we had not considered a pandemic outbreak. Thus, the main steps included were the following:

- A registration is required to enter the laboratory, in order to follow-up a possible viral rebound in our facilities.
- The use of mask is mandatory, in order to avoid a possible spread of the disease.
- Disinfectant gels and safety gloves are provided.
- Recommendation of notification if the worker has symptoms that are similar to those related to COVID-19 (especially cough, fever and shortness of breath).
- The promotion of telework as much as possible, by using software such as Zoom for online meetings, in order to avoid unnecessary face-to-face meetings.

To sum up, although it was a tough situation (personally, economically and professionally), coping with it has meant an enlightening experience, where we learned from the mistakes (and success) in order to improve the teaching experience. Even in these hard times there is room for learning and improvement, in this case for teachers and students. As the old saying goes:

“The man of little learning grows old like an ox; only his flesh grows but not his wisdom”.

4. Conclusions

The main conclusions that we have reached about how the coronavirus outbreak has affected the development of our normal activities are the following:

- For teachers, researchers and tutors, there was a considerable impact because many of their activities are based on face-to-face lessons or meetings. Nevertheless, the existence of an operating virtual campus and an online library has made the transition to telework easier.
- The development of new tutorials for these new users, and for further skills, was required, mainly due to the massive use of these resources.
- For students, there has not been a great impact from a technological point of view, as they are generally used to new technologies. However, the uncertainty generated at all levels (including exam dates) might have caused some discouragement, and affected their study process.
- Depending on the degree of completion of their degrees (or courses), students could advance at different levels. The completion of a FDP was not advisable under these circumstances when the student had more than three pending subjects if they wanted to finish the course in the calendar year.
- Concerning the laboratory work, the main disadvantage found, apart from the obvious interruption, was the spoilage of the vegetable oils used as raw materials for biodiesel and biolubricant production. That was the reason why the conclusion of the ongoing experiments was so important. Otherwise, they should be repeated as the sample would have changed its properties due to auto-oxidation, requiring the collection of new vegetable seeds for oil production at the right season.
- The development of alternatives (and further implementing of telework) for this kind of situations, such as hypothetical new outbreaks, is necessary. The possible mistakes made during this experience can be a valuable lesson in order to improve the teaching process at all levels.
- Finally, this experience can be a starting point for the massive implementation of virtual classes. However, face-to-face lessons also present many advantages in the education process, suggesting that, as Buddha recommended to Sona in the parable of the lute, the middle way might be the best one, alternating (in a balanced way) both online and face-to-face lessons when possible.

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