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Teaching Operating Systems in the Time of COVID-19

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Abstract—**The COVID-19 pandemic has made it necessary to adapt the methodologies used and the resources developed for face-to-face classes to support online teaching and learning overnight. This document describes the adaptation made in the context of the Operating Systems subject of the Computer Science Engineering studies at Universidad Autonoma de Madrid, to fulfill the new needs at the time of COVID-19. It includes details about the changes made regarding educational materials, communication among the different actors and evaluation approaches to fit the new requirements and engage the students. It also analyzes the results obtained by the students living this situation and compares them with those from the previous year.**

Keywords— higher education, COVID-19 adaptation, practical experiences, learning analysis, evaluation

I. INTRODUCTION

The COVID-19 pandemic has had a striking impact on many areas such as education, which had to move from face-to-face or hybrid approaches to online ones overnight. This has made it necessary for institutions and actors to adapt quickly to this new situation. Educational materials, teaching and learning strategies, methodologies and activities, communication ways, evaluation approaches, etc. have changed to fit the new requirements in this unforeseen context.

This has meant a shift for everyone, from educators to students and their families. New opportunities have arisen to demonstrate, once again, the usefulness of digital media as a support for addressing the new challenges in this context. Many articles are found related to adaptation to the COVID-19 time. In the context of education, some of them highlight the strengths, weaknesses, opportunities, and challenges of online learning in the time of crisis, such as [1]. In [2] the authors present a guide with recommendations to help teachers from face-to-face universities to address online evaluation. Other works focus on analyzing the effects of COVID-19 confinement on the autonomous learning performance of students in higher education [3]. In [4] the authors provide a timely map of the very diverse responses to COVID-19 in higher education contexts across 20 countries.

In this paper we focus on the decisions taken and the results obtained in relation to the teaching and learning of Operating Systems in the undergraduate studies of Computer Engineering at the Escuela Politécnica Superior (EPS) of the Universidad Autónoma de Madrid (UAM) in order to adapt to the new situation.

II. OPERATING SYSTEMS IN COMPUTER SCIENCE ENGINEERING AT UAM

For the sake of contextualization, this section briefly describes the contents, methodology and evaluation methods for teaching and learning Operating Systems in the Degree of Computer Science Engineering at the UAM.

The contents of the course are: (1) Introduction to operating systems, (2) Processes, threads, and process planning, (3) Concurrency, (4) Memory and virtual memory management, (5) I/O and file management and (6) Introduction to distributed operating systems and security mechanisms in operating systems.

The number of hours devoted to face-to-face sessions is 72, of which: 42 are dedicated to 1-hour long interactive lectures and problem solving, by students and teachers, in the classroom; 24 are used for 2-hour long sessions of programming practices with computers; and 6 are dedicated to exams in the classroom. The number of hours that students must dedicate to prepare the subject on their own, through non-presential activities, is 78.

The materials traditionally used during the course are the books [5][6], as the main bibliographic sources to study; PowerPoint presentations, used by lecturers as a script during classes and by students as a guide/summary of the content to study at home; collections of problems (both statements and solutions for some of them); guidelines for lab work; and exams.

To pass the course, it is mandatory to obtain a grade greater than or equal to 5 points in both the theory and practical parts of it, separately. If this condition is met, the final grade of the course is obtained through the equation:

$$Grade = 0.30 * Practice + 0.70 * Theory \quad (1)$$

Otherwise, the final grade is be calculated as

$$Grade = Min\ (4.9;\ 0.30 * Practice + 0.70 * Theory) \quad (2)$$

The theory grade depends on the evaluation modality: continuous or final. In either case, the written tests contain theoretical questions and problems to solve.

In the continuous assessment modality, attendance at face-to-face sessions is compulsory. Three midterm exams and one final exam are taken. The first midterm exam covers the contents of topics 1 and 2, the second one includes topic 3 and the last one covers from topic 4 until the end of the course. The final exam includes all the contents of the course and consists of 3 parts, each of which corresponds to the contents covered in the corresponding midterm exam. Students who pass any of the midterm exams (with a score of 5 or more) are exempt from taking this part in the ordinary final exam. Students who, having passed any of the intermediate exams, wish to try to raise their scores, may take that part in the final exam too. In any case, the theory grade is calculated as:

$$Theory = (Part_1 + Part_2 + Part_3) / 3 \quad (3)$$

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where $Part_x$, x$\in${1,2,3}, is either the grade obtained in the midterm exam x (in case of having passed it and not having repeated this part in the final exam) or the grade obtained in part x of the final exam. Most students are assessed on this basis of continuous evaluation.

For students who cannot attend face-to-face sessions or do not take any of the intermediate exams (the minority of them), the theory mark corresponds directly to the score they obtain in the final exam.

Regarding lab work evaluation, the students can be assessed either continuously or at the end of the semester. In the former, the work done during the whole term is considered; the students must attend all the practical sessions with computers in the laboratory; and they must submit the practical work by the deadlines established. The later includes a practical exam too, which exempts the obligation to attend labs, but not to submit the practical work by the established deadlines. The grade obtained by the students in continuous evaluation for the practical work is the weighted average of the marks obtained for the four practices made during the course. For those students who have not followed the continuous assessment itinerary, the grade is calculated as the weighted average of the mark obtained for the four practices and the mark obtained for a practice test. Students who do not pass must take a single extraordinary exam, which includes all the contents of the subject.

IV. TEACHING AND LEARNING ADAPTATION

On March 9th, the academic authorities of Universidad Autónoma de Madrid (UAM) and Escuela Politécnica Superior (EPS) asked students and teachers both to stay home from March 11th onwards, to avoid COVID-19 related risks, and adapt, as soon as possible, teaching and learning to this new situation.

At that time, the academical authorities of UAM recommended that face-to-face classes were not replaced only by online classes using Microsoft Teams. The need to use the institutional LMS Moodle as an asynchronous communication tool was highlighted, so that students could acquire skills and knowledge without accessing synchronous classes, since, on one hand, some of them might not have a good Internet connection at that time and, on the other, it might be difficult for the systems to support hundreds of groups of students at the same time, some of them including more than 200 students connected in the same channel. This was the case of Operating Systems, for which resources and methodologies were adapted to facilitate both synchronous and asynchronous teaching and learning.

A. Resources and Delivery

The materials, presentations and problem collections previously developed, which had been designed for face-to-face sessions and homework, served as the basis for recording videos to explain the contents and solve problems. Teachers used and annotated these materials while explaining. The teachers' aim was to enrich their set of educational resources to make them more self-contained and complete as well as to "simulate" dynamic teaching.

For example, some videos contained very short pauses in which the teacher posed questions. Although these pauses were extremely short, the aim was for students to feel challenged, to spend at least one moment thinking about the answer and, specially, to feel a sense of being in class, where interaction between teachers and students is very frequent in this subject.

All these resources (presentations, problem collections - some of them solved- and videos) were made available for the students through Moodle, so that they could interact with them asynchronously. Another key issue was that these materials were available little by little, gradually during the whole term according to the course planning, to keep the students engaged all the time. Sometimes additional (unplanned) resources were developed on the fly to satisfy the students' needs. For example, "a video has been published explaining how problem x (about which some of you had asked questions) is solved". This was very useful in motivating students to keep up with the study of this subject in a continuous way.

The means used for the adaptation and creation of educational resources were PowerPoint, digitizing tablets to draw or mark on the presentations when explaining, video recording tools (the operating system ones) to record the presentations, and Moodle to make the resources accessible and to perform tests.

B. New Instructions

The instructions for Operating Systems students to go from a mixed model, with face-to-face activities at the university (lectures, lab work, tutorials, etc.) along with homework (problem solving, practical work, studying) to a completely remote model, were to:

- Study the book recommended as the main bibliography source for this subject [5]. Given the huge amount of content to be addressed in Operating Systems, we use Stallings' book as support. For each subject, the teachers indicated which sections and pages contain the contents to be read and studied. This information was published all at once in Moodle, so that the students could see the magnitude of the contents to be studied and plan their dedication.
- Use the videos in which teachers explain content or solve problems, which were published gradually, as a mean to enhance subject comprehension and facilitate learning.
- Use the PowerPoint presentations delivered as a guide or summary of the main contents to be studied.
- Solve a set of problems from each subject, selected and proposed by the teaching staff to help the students maintain the pace of study throughout the term. The students can discuss the solutions in group and must send them for the evaluation modality to be continuous.
- Attend the planned online sessions in which the teachers explain or clarify certain issues, resolve doubts, give them instructions, or ask them about their progress, potential problems, etc. Sometimes the goal was simply to keep in touch, to engage them and to soften the sudden step from face-to-face classes, with almost daily contact, to asynchronous online learning (following the instructions received from our authorities).
- Carry out the planned programming practices, now at home instead of in the laboratory. The self-contained

statements and additional material deemed necessary in each case were published via Moodle.

- Deliver their programs via Moodle (as they did in the face-to-face context). Now they received personalised feedback as well as marks via Moodle too. The teaching staff for practical work explained the practical work to be done via MS Teams and stayed connected during lab time, available to answer any question. Questions received by e-mail, even out of this time, were replied too.
- Ask any questions as soon as they arise, both theoretical and practical, preferably using the Moodle forums, or contacting MS Teams in case of emergency.
- Take the theory and practice assessment exams from home (details will be provided below).
- Contact the teachers in charge of lectures and labs as soon as any needs or problems arise.

In terms of course planning, the schedule for practical work submissions was slightly modified to give students a little more time to adapt to the new situation. The scope and complexity of the last laboratory work was adapted to fit in with the end of the semester. Continuous assessment practical exams were conducted via Moodle in each group's timetable, in the class immediately following the submission of each lab assignment.

On the other hand, the date of the last mid-term exam (Midterm3) was changed, as it was originally scheduled to take place on the last day of the term, each group in its own timetable and classroom. In the new situation, all groups would do it at the same time, online. The delegates were contacted, and they confirmed with all the students that nobody had any problem with the new proposed date, thanking the teachers for having counted on them to agree it.

C. Communication

Both students and teachers used Microsoft Teams, Moodle and institutional e-mail to communicate. The main tool for resolving queries about specific course content was the Moodle forums. The teachers created a forum for each section of the course (thematic forums) and a forum for each online exam.

The thematic forums allowed students to ask questions during the course, and to respond to each other or to get an answer from the teachers. The fact that questions and answers were recorded allowed students to check, before asking a question, whether it had already been answered and to consult the reply in the forum. It also encouraged discussions among students (or between students and teachers) on different aspects of the course, specially on possible ways of solving certain problems.

Teachers also used the information posted by students in these forums to check how the course was going and to detect, for example, which aspects were causing the most questions or which students were having the most difficulties. On the basis of this information, teachers intervened by adapting the following activities, creating new materials or offering students online tutorials to clarify their doubts. Constant and continuous communication and interaction between students and teachers was also key to keeping them engaged.

On the other hand, the exam forums allowed teachers to give timely warnings to the whole class during an exam, if necessary. In fact, MS Teams was the main communication tool during exams and Moodle was used as an additional tool. In any case, the same information was sent through both channels during the exams.

MS Teams was the regular communication channel for synchronous online sessions, group tutorials and individual tutorials. It was also used during exams to allow students to ask specific questions about a particular statement (via private message to the teacher). Teachers responded either privately or to all of them if the clarification was deemed appropriate for all students. During the exams, teachers were not allowed to make use of webcams pointing at students, because of their institution privacy issues. Finally, MS Teams was also used by the teachers as the main tool for communicating and meeting, in a restricted channel available only to them. By combining the possibility of sending messages and making calls, it was a very practical tool for teachers too.

More traditional tools such as e-mail were also used by students and teachers for communication purposes. The latter have responded to messages received via e-mail, MS Teams or Moodle, regardless of the platform used by the students to send their messages.

All information about adapted contents, modified calendars, activities to be carried out and tools to be used was published in an addendum to the official teaching guide. From that moment on, the teachers continued to work on the development of educational resources and began to redesign the assessment to fit non-presential requirements.

V. Assessment

Given that the UAM is a face-to-face university, there was no institutional experience in conducting an entirely online evaluation. However, the teachers received some recommendations to face a quick adaptation [7].

They were recommended to use continuous assessment and take the exams via Moodle to ensure that the assessment answers were stored. They were also advised to design the tests so that they could be taken with students' notes, as there was no way to guarantee that they will not use them; the advice was not to focus so much on remembering, but on understanding, applying, analysing, evaluating, or creating, according to Bloom's taxonomy [8]. They were also given suggestions about potential resources for online assessment: questionnaires, problem solving, portfolios, discussions, etc. Finally, dissuasive measures were proposed to be applied to minimise the possibilities of plagiarism.

The university responsible contacted the students to find out about their possible technical difficulties and to offer help in those cases where it was necessary for them to continue learning online.

A. Exam Structure

Firstly, the teachers considered whether the type of assessment previously planned would still be valid in this situation or, otherwise, would have to be modified; they thought about it and designed the assessment questionnaires so that they could be taken online; they also established a protocol for assessment.

As it was described above, there were three midterm exams, Midterm1, Midterm2 and Midterm3. Except for Midterm1, the rest of the exams were taken online. The structure of Midterm2, Midterm3, the ordinary final exam and the extraordinary one was the same. It was formed by 4 Moodle questionnaires:

1) Honour Pledge: The students had to accept the following commitment of honour: "I promise on my honour that I will take the exam individually, without the help of any third party, without consulting any material or source not expressly authorised in the exam statement and without communicating with any person other than the Operating Systems faculty. I am aware that students who act without due probity will be sanctioned according to the ministerial order of disciplinary regime 17807/1954 and the UAM Student Statute".

2) Multiple choice test: A set of multiple-choice questions appeared, one question at a time, on the screen, in random order and with no possibility to change the answer back. For each question, we created a bank of equivalent alternative answers, with small changes (e.g. select true, select false - with corresponding adaptations to the answers). The order of possible answers to the same question was also randomised. The "clean" option was activated, in case they had marked an option but regretted it and preferred to leave it blank. Finally, only one attempt was allowed per questionnaire: once they pressed the "send all and finish" button, they could not return to modify it. Each correct answer scored 1 point, each incorrect answer subtracted 0.25 and blank answers were not scored.

3) Problems to be solved after the test in the order indicated for each student. They had to solve each problem by hand on a piece of paper, in their own handwriting, writing their name and the date at the top, and signing at the bottom. They then had to take a photo of it or scan it (each one could do what they liked best) and upload the file to Moodle (also in the format that suited them best: image, PDF,...). Finally, depending on each specific problem, that submission itself served as the answer or, if the problem involved calculations leading to a numeric result, they also had to type that result in a text box, or select it from a drop-down menu. Here again, only one submission was allowed.

4) Honour Pledge Confirmation: Confirmation that they had fulfilled the honourable commitment (answer yes/no). The text was identical to the initial honour commitment but changing the verb tense from "I promise on my honour that I will take the exam..." to "I promise on my honour that I have taken the exam...".

The timing of the questionnaires was set to make the test available first (20 minutes) and then the problems (40 minutes). The problems were activated 10 minutes before the end of the test, so that students who finished the test earlier could tackle them. During problem design, time for "logistical" issues (taking photos and uploading them, possible network cuts, etc.) was considered too. Students with special needs were given extra time as appropriate. The questionnaires were configured with customised time restrictions for them. For all students, if they did not send in the questionnaire within the set time, what they had done so far was automatically uploaded at the end of the examination time.

As this was the first time that hey had faced exams entirely online, to ensure that the procedure was understood and to confirm that there were no difficulties due to low-speed connections, we generated a simulation. We prepared a test with 4 questionnaires, with questions unrelated to Operating Systems, but with the same structure and type of questions that the exam was going to have. The students were asked to interact with it before the exam, so that they could see how it was going to be and could control the "logistical" issues: not being able to go back to the questions they had already answered, taking pictures and uploading them, checking the maximum size of the files, etc., in short, to put them in the right situation. We also took the opportunity to cut off the Wi-Fi and check that nothing was lost in Moodle: when the connection is recovered, everything done previously is still saved.

B. Dissuasive Measures

As it is not possible to guarantee that students will not use additional resources while taking the assessment tests, the teachers tried to design them so that it does not matter if the students have them. Among the test questions, most of them were not focused on remembering contents, but on understanding, applying, and analysing. On the other hand, the time available for answering the test was adjusted to the number of questions, to avoid extra time.

Attempts were made to minimise overlaps between students. The questions were displayed one at a time and each question was chosen at random from a bank of equivalent questions. The order in which the questions related to different topics were displayed was also random. The order of the answer options for the same question was random too, so that even if several students had the same question in front of them at the same time, the option with the correct answer (a, b, c, d) was not the same.

Penalising incorrect answers was also intended to minimise random or non knowledge-based responses. Correct answers were not shown until the exam had ended for all the students.

C. After the exam

Once the exam was over, students could check the correct answers to the questions they had to answer. They also had at their disposal the solutions to the problems proposed. For the review, a Moodle "query" was created for each student to tick off what he/she wanted to review, if it were the case. The teachers sent each student an e-mail reminding to consult the solutions and, if they still had doubts, they met in MS Teams to review what they needed.

D. Incidents

After each exam, in all the cases, there were some students who contacted their teachers saying that they had forgotten to fill in the confirmation of the commitment of honour. In these cases, the questionnaire was opened again so that they could fill it in.

Right after each exam, some students also contacted to say that, just when the time was running out, they were clicking "send all and finish" and they are not sure if whether the submission had been uploaded, so they attach their answers by e-mail.

Finally, when Midterm2 was over, a student contacted to tell that he had been wasting time compressing the photos he had taken with his mobile phone because he could not upload them, as they took up more than the maximum size allowed by Moodle. The exam was set to support a maximum of 2MB/file. This information had been notified to the students in advance, was indicated on the exam itself and was also the same configuration as the simulation quizzes that teachers created for them to "try out". In any case, from Midterm3 onwards this limit was set higher.

VI. Results and Analysis

To analyze the possible impact of this situation along with the changes made to learning and evaluation methodologies on learning outcomes, the statistics of the grades obtained by the students in the 2018-19 course (before the health crisis) were analyzed and compared with those from 2019-20. The grades obtained by students in the three midterm exams related to theory and taken during the semester (Midterm1, Midterm2 and Midterm3), as well as the grade obtained from the work done in the practical assignments (Practice), were analyzed.

The midterm exams are part of the continuous assessment modality. Since adhering to this modality is optional for students, not all students take them. In addition, not all those who start in this modality reach the end: some prefer to abandon it to join the final evaluation modality, which includes a unique final exam. This is the reason why fewer students take Midterm2 than Midterm1, and fewer students take Midterm3 than Midterm2.

On the other hand, there is also a continuous assessment itinerary for practical work. The final grade obtained by the students for their practical work is the one available for this analysis. In this case, the students preferred the continuous evaluation itinerary by far: there were fewer who dropped out. It is also worth noticing that these practices are carried out in pairs, which seems to produce an interesting effect on grades, as it will be discussed below.

Table 1 shows the sample population per course in each midterm and practice. The statistics of the grades obtained by the students in these two courses can be seen graphically in Fig. 1.

TABLE 1, Sample Population per Course in each Midterm and Practice

Course	Midterm1	Midterm2	Midterm3	Practice
2018-19	218	198	163	226
2019-20	217	216	204	230

The content in both years was exactly the same, and the organization and methodology followed until the adaptation to the new situation did not suffer variations either. Since Midterm1 took place under the conditions that preceded the confinement in 2019-20, the differences in averages between the two cohorts for the Midterm1 should only be due to the students' own performance. We can use these results as a baseline for comparing both groups. As it can be seen in Fig.1, the students of 2019-20 performed much better in Midterm1 than those in the previous year. In fact, the difference between both means (5.53 in 2018-19 and 6.79 in 2019-20) is statistically significant, as verified by Welch's t-test [9] for samples with different variances, with a p-value < 0.001.

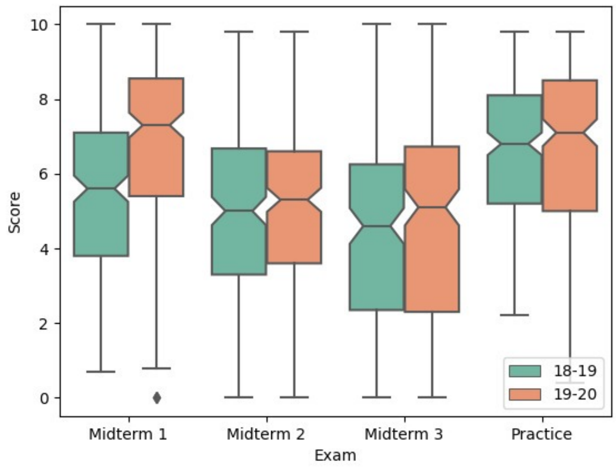
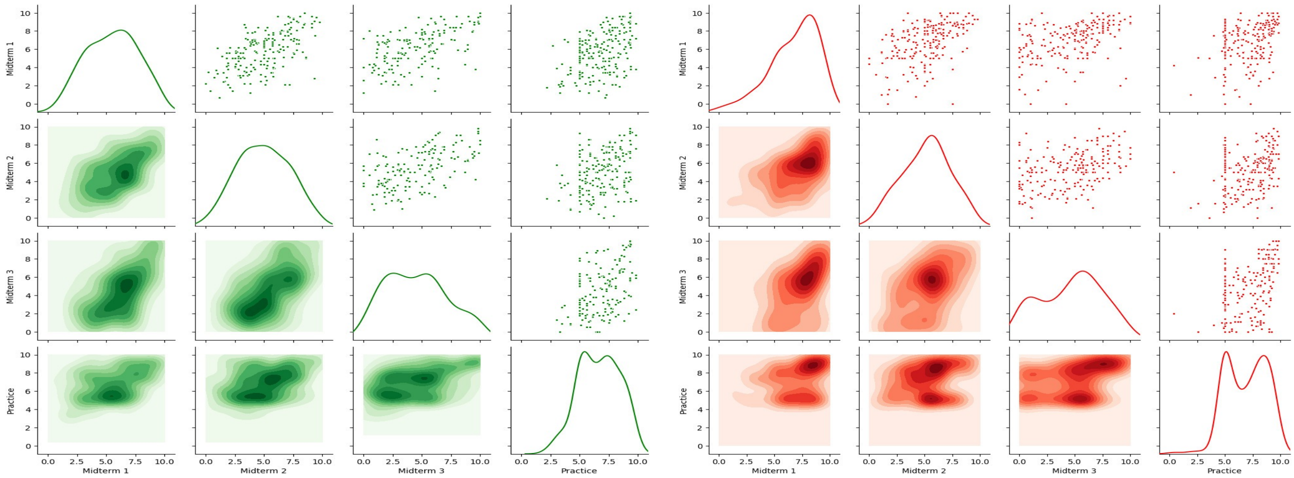


Fig. 1. Distribution of student's grades in 2018-19 and 2019-20

However, in Midterm2, which was already carried out in a confined situation, the students only obtained slightly better results than the previous year. Moreover, when moving the marks of Midterm2 of 2019-20 onto the same scale as the corresponding grades of 2018-19 (adjusting them according to the difference obtained for both cohorts in Midterm1), the average score is 4.22, i.e., much lower than 4.97 of the previous year. In other words, students in 2019-20 suffered a much more pronounced decline than their peers in the previous year. It may be worth mentioning that the level of difficulty of the different assessments was similar in both academic courses. The reason for this drop in performance is most likely due to the difficulty of both teachers and students to quickly adapt to the changes in teaching and learning methodologies as well as to the whole unexpected situation.

This average trend continues to be accentuated in Midterm3. However, the standard deviation of the grades increases (2.77, compared to 2.15 in Midterm2, also noticeable in Fig. 1). This may indicate that different groups of students reacted differently to the changes, some being able to adapt better than others. This is also reflected in the different quartiles of the grades for Midterm2 and Midterm3 in 2019-20: in Midterm2 25% of the students had a grade lower or equal to 3.60, while in Midterm3 the 25% with the worst grade obtained 2.30 or less; in the same direction, the 25% best grades in Midterm3 were 6.73 or more, while in Midterm2 the 25% best grades started at 6.60. Even analyzing the median (50th percentile), as it can be noticed, the trend is reversed, and the median for Midterm3 is much better in 2019-20 than in 2018-19.



a) b)

Fig. 2. Distribution of grades for the 3 midterm exams and practice works (main diagonal: from top left to right bottom); probability density (lower left corner) and scatter plots (upper right corner) regarding pairs of evaluations, corresponding to: a) 2018-19 and b) 2019-20

These conclusions are reinforced by cross-checking the data. Fig. 2a shows this comparison for the non-COVID-19 course and Fig. 2b shows the graph of the course in confinement and new normality: grade distributions for Midterm3 and practice works are shown in the main diagonal (from top left to right bottom); probability density is shown at the lower left corner; finally, scatter plots regarding pairs of evaluations are shown at the upper right corner.

In the diagonal of both figures the distribution of grades of this midterm can be seen. The relevant observation to highlight from these figures is that the distribution of Midterm1 in 2019-20 presents clearly better results than in 2018-19, while in Midterm2 this difference is reduced. It is in distributions of marks for Midterm3 where a striking behavior is found; it is bimodal. This implies that there are two clearly differentiated behaviors, as seen in the analysis of means and quartiles. While the highest peak is located at a normal value (slightly above the central value), the second mode is presented well below the minimum mark to pass (5.0).

The second peak represents students who have the least expectation of passing by continuous assessment. They keep on taking the exams, but without much motivation, which is reflected in the grades. It is interesting to note that this phenomenon also occurs in the previous course, but at that time there were more students in that situation who nevertheless obtained better grades (i.e., they dropped less). In other words, in this course, with the COVID-19 restrictions, there were fewer students who lost motivation, but the disconnection of these was greater.

However, regarding practical work, the behavior is very different: it is bimodal too, but here it is due to a completely different reason. Given the difficulty of the subject, the number of repeating students is high. All those who got a mark higher than 7 for the practical work done during the previous year can apply for what the teachers call "validation": if they do not wish to repeat practical tasks, the mark for this part of the course, which will be used to calculate the final grade of Operating Systems, will be 5. Looking at the mode on the right, the results are better in the COVID-19 year than in the non COVID-19 one, although this difference is not so noticeable in the average, because of the impact of "validations".

The graphs below the diagonal show the density of the probability that a student who has obtained a certain mark in one midterm exam or lab work will obtain a certain mark in another midterm exam or lab work. Ideally, if all students obtained an identical mark in all exams, the probability density would be a line from 0.0 to 10 with a peak at the mark with the highest incidence.

In this direction, it can be observed that Midterm1 and Midterm2 have this behaviour with the associated statistical deviations and with the maximum shifted so that students who had obtained a 7 in Midterm1 would tend to obtain approximately a 5 in Midterm2. This result is congruent with the distributions of marks shown in Fig. 1. The probability density between Midterm1 and Midterm3 shows a greater dispersion of values. However, bimodal behaviour is evident between Midterm2 and Midterm3. This behaviour shows that those who had obtained only the minimum mark required to pass Midterm1 and Midterm2 tend to fail Midterm3. The second (maximum) mode indicates that there is a significant group of students who maintain their relatively high marks, around a B.

The probability densities of the midterm exams with respect to practices are more striking. The probability density of Midterm1 with respect to the practices is slightly bimodal; it becomes clearly bimodal in Midterm2; and, finally, it shows 4 or 5 modes in Midterm3, for both years. We can see that the number of students with average marks (around 5) in practices and low marks in Midterm3 is significant. It should be taken into account that many of these students had their practices validated, which leads us to think that the validation of practices does not make it easier for students to pass the theory. However, this behaviour occurs to a much lesser extent in a confinement situation (Fig. 2b).

Finally, with respect to Midterm3, this distribution becomes penta-modal in the case of normality and tetra-modal in the case of confinement. The double mode of good and very good grades in the normal year becomes a single mode of very good grades in the COVID-19 course. This allows us to infer that students with good marks have been able to focus much more on the course taught with the new methodologies. The other three modes remain almost unchanged.

The two lower modes are of students who are demotivated with the subject: one mode is of students who, despite their demotivation, continue with the subject and manage to pass, and the other is of those who give up on passing the theory in the continuous mode and focus on the practical work. Finally, the small node with high marks in practical work and very low marks in theory corresponds to students who have a motivated practical partner with good marks but who lose the motivation to pass the subject in the continuous modality. The fact that the practical work is carried out in pairs leads us to think that we need to think of a way to allow high level students to positively influence their classmates in these cases.

Finally, in order to get clues about the goodness of the assessment, it is worth asking whether there is a correlation between the different midterms and between the midterms and the practice. The correlation between the different distributions is calculated and the results are shown in tables 2a and 2b, for the non-COVID-19 and COVID-19 courses, respectively.

TABLE 2A, CORRELATIONS IN 2018-19 (NON-COVID)

2018/19	Midterm1	Midterm2	Midterm3	Practice
Midterm1	1.00	0.50	0.43	0.32
Midterm2	0.50	1.00	0.46	0.28
Midterm3	0.43	0.46	1.00	0.40
Practice	0.32	0.28	0.40	1.00

TABLE 2B, CORRELATIONS IN 2019-20 (COVID)

2019/20	Midterm1	Midterm2	Midterm3	Practice
Midterm1	1.00	0.58	0.54	0.42
Midterm2	0.58	1.00	0.55	0.32
Midterm3	0.54	0.55	1.00	0.45
Practice	0.42	0.32	0.45	1.00

In educational contexts, correlations above 0.5 are considered very good, between 0.4 and 0.5 are normal, and below 0.3 are bad. As can be seen in table 2, in general, the correlations of the COVID-19 course are better than the correlations of the non-COVID-19 course. This is explained by the fact that the study conditions are at the same time more flexible and stable over time. More flexible because they allow students to better organise their work schedules and more stable because there are no external influences on the schedule.

Likewise, there are some values that stand out because they do not correlate well; all of them correspond to practices. Most striking is that the lowest of these correlations is with Midterm2. It is the most striking because most of the knowledge that is put into practice corresponds to the theoretical knowledge assessed in this part. This may be due to the fact that this group of students who do not obtain very good marks work in practice with students with good marks. This reaffirms the need to think about how the latter can influence the former.

VII. CONCLUSIONS

In this paper we have presented our experience in adapting the Operating Systems course for Computer Engineering students at the Universidad Autónoma de Madrid in the 2019-20 academic year to adapt it to the COVID-19 pandemic situation.

First, we adapted the educational resources and created new ones for the students to interact with. We sought a balance between providing the materials in advance, so they could organize their time as they preferred, and delivering the new resources gradually, to keep them engaged throughout the term.

In some cases, additional (unplanned) resources were developed on the fly to meet the needs of the students. This, along with the continuous interaction between students and teachers through Moodle forums and MS Teams, was very helpful in keeping students engaged.

The synchronous group tutorials were very enriching, not only academically but also personally. During the whole term there was a very good atmosphere, and we could feel the collaboration of the students in adapting to the new situation and their appreciation for our work. The mutual perception of striving to make the best of the learning process in this situation was also engaging for students and teachers.

As for the evaluation, our first impression was that they had been honest in general. We suppose that the deterrents adopted also played a role: they had only one question in front of them at each time; they did not all have the same questions but variations; the order of presentation of the questions was random; they did not know the following questions to be solved in advance; they could not go back to rectify; they did not have much extra time to take the exam; they had to sign commitments before and after the exams; etc. We believe that all these together helped them to focus on their own questions at every point of the exam.

On the other hand, having interacted with a simulation before each exam helped them to know what to expect (type of questionnaires and restrictions, modes of delivery and uploading, etc.) and, therefore, to reduce their nerves about "logistical" issues during the exam.

With respect to the results observed, the adaptation of the students to the COVID-19 situation was a little slow, with an impact at the beginning (Midterm2 midterm exam). This adaptation was different according to the student's typology, increasing the previously existing differences. Highly motivated students obtained better results and produced higher motivation in the average student, while it seems that unmotivated students became even more demotivated. Since motivation is conditioned by proactivity, we should find a way to promote proactivity in low motivated learners. In addition, we should find a way for motivated students who get good grades to spread motivation to their peers.

The analysis conducted suggests that allowing students who had successfully completed the practical work the previous year (score > 7) not to do this task again does not have a positive effect on their learning, at least in this pandemic situation.

The assessment approach followed during the course seems to have worked well, since the correlation of results is good enough in any situation, both confined because of COVID-19 and non confined. Moreover, the grades corresponding to online midterm exams show a stronger correlation between them. Finally, the low correlation between the theory and practical marks related to the different student profiles found, as described in section V.

During this time of confinement, we also have the experience (in another subject) of a HyFlex (hybrid, flexible) model, where students attended classes online synchronously and could view the recordings later. We are planning to analyse and report that experience too, and compare it with this one, to get conclusions about which practices seem to result better and regarding the impact of the course context in the results obtained.

We would like to analyse the usefulness and feasibility of bringing previously proposed approaches related to adaptation in e-learning [10] back for present and future e-learning. Finally, it would be interesting to reflect on the lessons learned in previous experiences of learning analytics in higher education [11] and on their potential application to engage the less motivated students and prevent them from failing.

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