The teaching-learning process in specific engineering subjects through different technology-based teaching methodologies applied during the State of Alarm

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**Abstract**: The safety measures contemplated in Real Decreto 463/2020, of March 14, which declares the State of Alarm for the management of the health crisis situation caused by COVID-19, determine the temporary suspension of the face-to-face educational activities and establish that these will have to be developed through distance and online modalities. This fact, which conditions traditional face-to-face teaching, forced us to look for new alternatives to meet the teaching objectives. This article presents the results and qualifications obtained by the students in the application of three different teaching methodologies in the teaching of the subject Manufacturing Processes II, of the University Center of Mérida in the Degree in Engineering in Industrial Design and Product Development (GIDIDP). The main objective has been to evaluate the influence of the different methodologies on the qualification of the students and the skills acquired. In the analysis of the results, in the application of the different methodologies, no significant differences have been obtained. The students assimilated the required competencies in a satisfactory way.

**Keywords**: Teaching methodology, Synchronous, Asynchronous, State of Alarm, Higher education eLearning.

1. Introduction

In the first days of March 2020, the institutions ordered the confinement of the population in their homes due to the global pandemic caused by the SARS-CoV-2 virus that causes the COVID-19 disease. This measure was approved by the state of alarm of March 14 [1] and subsequent measures of March 29 [2] that tightened the confinement, paralyzing the non-essential activity of the country, including the educational activity [3].

Suspending face-to-face teaching meant a quick and immediate adaptation to other types of teaching and evaluations. This step from face-to-face teaching to online teaching was assumed by teachers and students immediately without having prior planning.

In the same month of March, the Spanish Network of University Quality Agencies (REACU) informed all the quality evaluation agencies that in their evaluation processes they would commit to recognize the changes that each university had to introduce for the adaptation of teaching and evaluation during the pandemic, always under the European, national and regional premises and [4].
Later in April, REACU made a new communication to adopt evaluation methodologies using the available resources and aligning with the quality standards of the European Higher Education Area (EHEA) [5], based on the following general criteria:

- Different evaluation methods, based on continuous evaluation techniques and individual tests.
- Allow to evaluate the acquisition of skills and learning outcomes of the subjects.
- The evaluation methods, like the evaluations, must be made public previously [4] and included in the teaching guides of the subjects as addenda [6].

With this background, it is important to highlight the student's previous teaching experience, changing from a face-to-face modality to a completely virtual one. Although currently most of the students dominate the technologies, being called the Z generation [7], it was important to establish a communication channel to explain the steps to follow the non-face-to-face teaching.

According to studies based on objective data such as abandonment rates or the percentage of students who complete studies [8], in disciplines related to engineering pose a challenge and a high difficulty for students and teachers.

The age group of the students of these subjects has grown in technological development and they believe that this will be the element that essentially defines the characteristics of the labor market [9].

It is important to highlight that the change, due to urgency, had to be carried out in the middle of the semester, which meant a greater effort on the part of teachers and students. Nor was there a planning of technological means, so that the acquisition of other digital skills necessary to address the appropriate educational level, were implemented and assimilated from the beginning, which could mean, according to some authors, the increase of the following three inequalities [10]:

- Access to electronic devices and internet connection.
- Time of use and the quality of it (sharing device by several family members).
- Competences of teachers and students for the proper use of digital platforms for educational purposes [11].

Evaluation is for many authors one of the difficulties that the teaching team would encounter, becoming a critical point for online teaching [12].

In this environment full of difficulties and challenges, the teachers proceeded to adapt the contents so that they could be taught synchronously and asynchronously, having to generate new content or adapt existing ones to a virtual environment. The interaction between students and teachers is the first concern in this new purely digital approach, since it is necessary to supplement the advantages that human interaction offers in face-to-face classes [13].

This article aims to demonstrate, with objective data obtained in the application of non-face-to-face methodologies, that the competences have been successfully acquired by students, making a comparison between the face-to-face part of teaching and those that were taught synchronously and asynchronous.

We will take advantage of the conclusions and results of this article to give a voice to those authors who think that virtual teaching will be the next teaching-learning model. According to Torrecillas [14], due to the pandemic and the forced introduction of online classes, Spanish public universities did not have the experience factor incorporated into their background. In fact, in percentage terms, only 3.45% of public universities taught non-face-to-face teaching in the 2018-2019 academic year, compared to 62.54% of private universities [14].

We will show the methodology developed and the results obtained in the final evaluation by the students after the application of the three methodologies that coexisted during the first months of the pandemic: face-to-face, asynchronous and synchronous, in the subject Manufacturing Processes 2 (PF2), for a total of 46 students, where 39 took the final evaluation tests and the rest NP (Not Presented).
2. Methodology
For the application of the planned teaching methodologies, it was necessary to satisfy the first requirement approved by the University of Extremadura on April 12 and included in the “ADDENDUM ACADEMIC CRITERIA FOR ADAPTATION TO NON-PRESENTIAL TEACHING DURING THE DECREE OF ALARM STATUS BY COVID19 ”, Where the need to transform teaching activity to a non-face-to-face format is specified, adapting teaching methodologies and evaluation systems without leaving behind the acquisition of competences [15].

In the PF2 subject, it was decided to apply the three methodologies available by the addendum:

- **Face-to-face teaching.** Teaching activity that requires and demands the presence of the student in the classroom, where learning is directed by teachers, who in their most traditional role explain, clarify and communicate ideas and experiences [16].

- **Synchronous virtual class.** Teaching activity that is developed through an interaction between teachers and students, which requires the coincidence of both at the same time (synchronous presence), using technological communication tools such as, for example, chat, videoconference, among others [11, 15].

- **Asynchronous virtual class.** Teaching activity in which teachers and students interact flexibly, at different times. Some teaching activities in this category are: reading documents, viewing videos of theoretical content, viewing tutorials on problem solving and / or practical cases [15].

The PF2 subject is divided into 10 topics which were classified as follows (see table 1) for the application of the different methodologies described above. The first topics were already covered by face-to-face teaching, the rest were divided between synchronous and asynchronous teaching:

| Teaching      | Subjects          |
|---------------|-------------------|
| Face to Face  | 1, 2, 3, 4        |
| Synchronous   | 5, 6              |
| Asynchronous  | 7, 8, 9, 10       |

Classes have been taught in a traditional way through face-to-face teaching, with the teacher and students in the classroom and making the presentations and providing the appropriate explanations directly in the classroom, for Topics 1, 2, 3 and 4. With the synchronous teaching modality, it was proposed to replace face-to-face teaching with online teaching, with direct interaction between the student and the teacher, through a virtual classroom and by videoconference, for topics 5 and 6 (see table 2). And finally, in asynchronous teaching, students were proposed to access the content and explanations on demand through the Virtual Campus of the subject, each student could follow the teaching on the day and time that was most convenient for them, to topics 7, 8, 9 and 10.

| Table 2. Non-face-to-face teaching methodologies. |
|-----------------------------------------------|
| **SYNCHRONOUS VIRTUAL CLASSES**               |
| Live lecture classes                         |
| Specialized presentations                    |
| Problem resolution                           |
| Virtual practices                            |
| Collaborative group work coordinated by the teacher |
| **ASYNCHRONOUS VIRTUAL CLASSES**             |
| Reading documents                            |
| Creation of short videos uploaded to the virtual campus |
| Generation of explanatory pdf with questionnaires |
In order to meet the criteria and evaluation requirements approved by the UEx, a series of adjustments had to be made to adapt them to the new proposed methodologies and teaching activities. In this sense, it was proposed that alternative evaluation activities be included to be carried out electronically through the Virtual Campus. In the case of the final tests in the continuous evaluation mode, it had to be taken into account that the content taught in person had not reached 50% (see table 3), so the final tests should not exceed this percentage in the final qualification. And in the case of the global evaluation, the final tests would be 100% [15].

### Table 3. Percentages of teaching methodologies.

| TYPE OF ACTIVITY                                      | PERCENTAGE |
|-------------------------------------------------------|------------|
| Activities related to the synchronous virtual class: |            |
| Solving questionnaires, attendance, etc.              | 20%        |
| Activities related to the asynchronous virtual class:|            |
| viewing videos, reading documents, solving            | 20%        |
| questionnaires, etc.                                  |            |
| Evaluation activities developed in the previous face- | 20%        |
| to-face training                                      |            |
| Final test                                            | 40%        |

All these changes were notified to the students through the recommendations contained in the document “Planning of the PF2 students”, which also included the programming of the subject for the rest of the semester, so that the students could clearly know how to proceed in non-face-to-face teaching.

It was also indicated that topics 7, 8, 9 and 10 would be made available on the virtual platform in PDF format and videos with detailed explanations of their content. These last topics would be reinforced with evaluation questionnaires and that would later serve us to contrast the results we were looking for to analyze the impact of each applied teaching methodology.

Finally, and due to the uniqueness of the entire process, two exam protocols were drawn up for the June and July calls, these were collected in two similar documents with the title "Examination protocols for the PF2 subject" and which is not relevant to show in this article because they have no relevance to the discussion of results we are looking for.

### 3. Results and Discussion

The results shown below are classified according to the type of teaching followed and the results obtained by the students in the qualification, in this way we can make an objective comparison on the impact it has had on the students and their final grades. The results of the theoretical questions of the final exam that correspond to the classroom teaching will be compared with the results of the theoretical questions of the final exam of synchronous and asynchronous teaching. The data from the evaluation questionnaires of topics 7, 8, 9 and 10 will also be crossed during the asynchronous modality to observe if there are differences between this modality and the final test.

For a total of 39 students who appeared in the final test, the scores are shown in the following table (see table 4). These have been obtained by answering up to a total of 50 questions divided by topics. Table 5 shows an example of the qualifications obtained by topics.

### Table 4. Results of the final test by subjects and students.

|                      |            |
|----------------------|------------|
| Students with grades > 5 | 25         |
| Students with grades < 5 | 14         |
| Success rate (>5)    | 64.10%     |
Table 5. Sample of grades by topics and questions.

| Topic 1 | Topic 2 | Topic 3 | (…) | Topic 10 |
|---------|---------|---------|------|----------|
| Question 1 | 0.2 | -0.06 | 0.2 | (…) | -0.06 |
| Question 6 | 0.2 | 0.2 | -0.06 | (…) | -0.03 |
| Question 14 | 0.2 | -0.06 | 0.2 | (…) | 0.2 |
| (…) | -0.06 | -0.06 | 0.2 | (…) | -0.06 |
| (…) | (…) | (…) | (…) | (…) | (…) |
| (…) | -0.06 | 0.2 | -0.06 | (…) | 0.2 |

Student 1

Student 2

Student 3

Student 4

Student 5

Student 39

The previous table shows the results obtained by each student (rows), each column corresponds to a question. Values that are scored as 0.2 mean that the answer is correct, values that mark -0.06 the answer given by the student is incorrect, and values of -0.03 mean that the answer has been left blank or without answer by the student.

The table below (see table 6) contains a summary of the ratings categorized by topic.

Table 6. Final test results by topics.

| Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5 | Topic 6 | Topic 7 | Topic 8 | Topic 9 | Topic 10 |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| SUCCESS | 126     | 236     | 146     | 100     | 88      | 151     | 116     | 106     | 86      | 66      |
| BLANK   | 16      | 16      | 6       | 6       | 23      | 2       | 6       | 26      | 25      | 37      |
| FAILURE | 47      | 51      | 38      | 38      | 39      | 42      | 29      | 45      | 55      | 37      |

Based on these results, in the following table (see table 7) we separate the questions by methodologies, identifying the correct answers, the errors and the blank answers for each one of them. The graph following the table (see Figure 1) shows the summary and graphical representation of the results obtained, also identifying the importance of each methodology of the teaching provided. In blue the questions from the face-to-face mode are shown, in red the synchronous teaching and the asynchronous teaching in green.

Table 7. Results of the final test in face-to-face, synchronous and asynchronous teaching.

| Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5 | Topic 6 | Topic 7 | Topic 8 | Topic 9 | Topic 10 |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Face-to-face teaching | SUCCESS | 126     | 236     | 146     | 100     | 88      | 151     | 116     | 106     | 86      |
| Face-to-face teaching | BLANK   | 16      | 16      | 6       | 6       | 23      | 2       | 6       | 26      | 25      |
| Face-to-face teaching | FAILURE | 47      | 51      | 38      | 38      | 39      | 42      | 29      | 45      | 55      |
| Synchronous | SUCCESS | 66%     | 77%     | 76%     | 69%     | 58%     | 77%     | 76%     | 59%     | 51%     |
| Synchronous | BLANK   | 47%     | 51%     | 47%     | 51%     | 47%     | 51%     | 47%     | 51%     | 47%     |
| Synchronous | FAILURE | 47%     | 51%     | 47%     | 51%     | 47%     | 51%     | 47%     | 51%     | 47%     |

We can highlight, regardless of the teaching modality and in practically all the cases, that more than half of the answers were indicated as correct. Only Topic 10 with a success rate of less than fifty percent (47%) and Topic 9 (51%) stand out within the asynchronous methodology.

As topics 1, 2, 3 and 4 face-to-face teaching, topics 5 and 6 synchronous teaching and topics 7, 8, 9 and 10 asynchronous teaching, we can summarize the importance of the successes of each topic by comparing it with the number of questions in the same topic in the final exam, in the following tables (see tables 8 and 9).
Figure 1. Results of the final test in face-to-face, synchronous and asynchronous teaching.

Table 8. Number of questions per topic in the final test.

| TOPICS | Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5 | Topic 6 | Topic 7 | Topic 8 | Topic 9 | Topic 10 |
|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Questions | 5       | 8       | 5       | 4       | 4       | 6       | 4       | 5       | 5       | 4       |
| %       | 10,00%  | 16,00%  | 10,00%  | 8,00%   | 8,00%   | 12,00%  | 8,00%   | 10,00%  | 10,00%  | 8,00%   |

Table 9. Success, failures and blank answers by topic, according to the importance of the topics.

| TOPICS | Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5 | Topic 6 | Topic 7 | Topic 8 | Topic 9 | Topic 10 |
|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| SUCCESS | 25,20   | 29,50   | 29,20   | 25,00   | 22,00   | 25,17   | 29,00   | 21,20   | 17,20   | 16,50   |
| BLANK   | 3,20    | 2,00    | 1,20    | 3,50    | 5,75    | 0,33    | 1,50    | 5,20    | 5,00    | 9,25    |
| FAILURE | 9,40    | 6,38    | 7,60    | 9,00    | 9,75    | 7,00    | 7,25    | 9,00    | 11,00   | 9,25    |

Being the mean of correct answers of the ten subjects 25.08, the subjects that deviate significantly are subjects 9 and 10. Although the failure rate remains within the mean, having an increase in the number of blank responses. These differences may be due to the complexity of the change to a third modality, as well as to the fatigue of the student in the final phase of the subject.

To finish certifying these differences, we will use the Evaluation Questionnaires that were carried out during asynchronous teaching. We can see in the following table (see table 10) the results of the CE of Topics 8, 9 and 10. We will focus on Topics 9 and 10 since they are the ones that offer different results in the final test. The table shows the results obtained by the students in each CE, as well as the success rate considered when a grade equal to or greater than 5.00 is obtained.

Table 10. Results of the CEs of Topics 8, 9 and 10.

| CE – T8 | CE – T9 | CE – T10 |
|---------|---------|----------|
| Students with grades <5 | 0 | 0 | 2 |
| Students with grades > 5 | 33 | 33 | 31 |
| Success (> 5) | 100% | 100% | 95% |

These general results stress the importance of the use of new technological resources in the intellectual work, providing more clear sightedness in the teaching-learning process, and therefore, highlight the TIC’s importance as an instrumental resource.

4. Conclusions
The conclusions obtained from this study show a rapid adaptation of the students to the different proposed methodologies, obtaining similar results in each one of them, so that the students have acquired the competences regardless of the teaching methodology used. The initial thoughts of the authors...
assumed that the application of the different methodologies could suppose difficulties of adaptation in the assimilation of competences.

Possible small deviations between one methodology and another come from the greater interest shown by students in face-to-face teaching. The deviations produced in the last subjects of asynchronous teaching are corrected by means of the realization of evaluation questionnaires during the period of asynchronous teaching.

Of the 46 students enrolled in the subject, 39 took the final exam obtaining a satisfactory score 22 of them. 56% of the students passed the subject through the three methodologies developed during the course, these data present satisfactory results compared to previous years of only face-to-face methodology.

The intention of the authors is to replicate the study during the years 2021 and 2022 to obtain a comparative analysis of three consecutive years and to be able to reach higher and better-founded conclusions.

Finally, it should be pointed out that the Non-face-to-face teaching methodologies, although positive in their outcome in term of results and the teaching-learning process, they do require a considerable effort of coordination on the part of teachers.

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