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Impact of COVID-19 on the Teaching and Learning of a Graphic Engineering Course*

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The current situation derived from the COVID-19 crisis is generating unprecedented challenges throughout the educational community, although higher education institutions have demonstrated their ability to adapt very quickly and with great flexibility to the crisis. Since the beginning of the pandemic, students are experiencing new learning environments and employing a broad set of resources whose impact on their overall learning has yet to be discovered and is being investigated. There are also many unknowns to solve about how the lockdown has affected them.

This research provides new evidences on this unprecedented phenomenon about aspects related to their learning and their effect on confinement in a Graphic Engineering subject through a cross-sectional survey conducted with a students' group (n = 264) during the pandemic period using triangulation of data analysis. A quantitative comparison of the final marks of the students has also been made between the emergency situation and the one before the confinement.

The results show a clear and direct relationship between academic performance of the students in pandemic period and variables such as the degree of attention, the time spent on assigned tasks and the conditions of the workspace. The best evaluated training activities are the project and the exercise videos. In general, women are more satisfied with their academic performance and evaluate the practices more positively than men. Although the responses of women have been found to have somewhat more variability than those of men, no meaningful results can be extracted. Final marks and the marks of the autonomous learning competence of the subject increased slightly at the beginning of the pandemic period compared to previous periods, but in the following quarter of confinement the marks were maintained or even decreased with respect to the pre-pandemic period. Finally, the study identifies best practices that will be of value for distance teaching and engineering education beyond the pandemic situation.

Keywords: engineering education; graphic engineering; distance learning; COVID-19 pandemic; academic development

1. Introduction

1.1 Theoretical Framework

Closing universities and cancelling all face-to-face activities have become an inevitable reality in most parts of the world. Universities are progressively reformulating and adapting new learning activities and different assessment methodologies derived from distance education [1–4]. For engineering schools, this change has been a great challenge since laboratory classes and practical applications in which direct contact between students and teachers and teamwork between students are an essential part of the curriculum. The exceptional situation generated by the COVID-19 pandemic allows studying how distance education has impacted all students, even those who would not have chosen online studies and degrees such as engineering that are generally not offered online.

In the previous literature on the factors that intervene in the transition towards distance education models, the perceived quality of the courses and how the classes are taught have been highlighted as decisive factors in students' satisfaction and learning process [5–7]. For this reason, it is crucial that when designing online courses take into account the adaptation of the content to online platforms, the pedagogy, the methodologies, and the technology used to implement them [8].

Due to the unprecedented context derived from the COVID-19 pandemic, the literature on the impact of this sudden transition to online education methods on engineering studies is still limited [9, 10]. Furthermore, although some studies try to

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identify the impact of distance learning on students' academic development and the variables that have intervened, the results show contradictions and are not conclusive. Some studies point out that the lockdown has not affected the students' performance and their outcomes [11, 12], as in the case of the research in engineering studies by Jacques et al. [13] in which it is shown that the students' performance has not been reduced and that the grades they obtained are similar to those expected in face-to-face teaching. However, other studies show that students are concerned about the negative impact that the situation will have on their academic results [14, 15], and indicate that during distance classes the performance has decreased [8]. The lack of consistency in the results of the studies can be due to different factors such as the measures that each country implemented to face the health crisis and the lockdown conditions, causing that in some countries classes were suspended from the beginning of the pandemic, while others only reduced the proportion of face-to-face classes or postponed the start of the semester [16]. Other factors that can cause these variations in the results may be the resources available to students, the teaching methodologies used in each subject and university, and the differences between the academic fields that make some degrees more challenging to adapt to distance teaching. For this reason, new studies are needed to provide evidence on the impact that the transition to distance learning has had on students from different countries and academic areas during the COVID-19 pandemic.

Other issues that have received attention in the literature during COVID-19 have been the adaptation of classes and exams to distance teaching and the support students have received from their teachers, although contradictions are also found in the assessment that students make of these aspects. In some studies, students are less satisfied with distance classes and assessment methods compared to face-to-face education [17] and show dissatisfaction with the support received from their teachers [18], which in turn is related to an increase in the perceived workload [15–19]. In the study by Tang et al. [20] on engineering students, it is shown that students are generally dissatisfied with the impact of online courses on their learning. This dissatisfaction with the quality and the implementation of the distance classes can become a barrier to the acquisition of knowledge and the commitment of the students [12]. For example, Hamman et al. [21] suggest that those students who have received the classes online during the COVID-19 pandemic are less likely to be successful than those who have received face-to-face classes. On the other hand, some studies show that students are satisfied with the classes and the support received from the teaching staff during the online learning [13–22] and that they think that the evaluation methods have been duly adapted to non-face-to-face teaching [23].

Previous studies have described the lockdown situation as an unpleasant experience that can involve boredom and uncertainty [24, 25] and reported adverse psychological effects that can cause to the people who suffer it [26]. However, in situations such as the COVID-19 health crisis, it is necessary to implement lockdown measures to stop the virus's spread, so it is necessary to investigate how to reduce its negative impact and minimize the negative feelings generated by the isolation. Research in pedagogy and education indicates that interactions between students and with teachers are essential for academic performance and students' satisfaction [27–29], so the isolation caused by lockdown implies a significant challenge in the educational experience of students [29]. In confinement situations, having a good contact with other students and teachers can reduce the negative impact of the lockdown on students' mental health [30–32]. In contrast, the lack of these relationships with the academic community is related to greater academic stress [33], so the adverse psychological effects of lockdown on students can be increased if there is a lack of interaction with their peers and teachers.

In Spain, Royal Decree 463/2020 [34], of March 14, which declared a state of alarm for the management of the health crisis situation caused by COVID-19, declared in its article 9 the containment measures in the field of education and training, and suspended face-to-face educational activity in all centers and stages, cycles, degrees, courses and levels of education, including university education, as well as any other educational or training activity taught in other public or private centers. During the entire suspension period, educational activities would be maintained through distance and online modalities, whenever possible. For this reason, the elements of the training programs were inevitably altered, such as face-to-face training activities, laboratories and internships, external internships, Erasmus and other mobility programs, etc. The Spanish public universities (autonomous entities) agreed that all the classes and the evaluation processes should follow their normal course but adapted to the non-face-to-face format and always respond to the European criteria and guidelines, especially in the quality assurance considerations applied to the online teaching.

Based on the context of the aforementioned literature, this work considers the effects caused by the pandemic and confinement (since March

15, 2020) in students enrolled in the subject of Graphic Engineering (GE) and aims to provide new empirical data that shed light on issues for which there is still no consensus in the scientific literature. The research presented in this article analyzes and discusses how, based on confinement, educational strategies have had to adapt to the available resources to develop an adapted e-learning context to improve student training.

This research also aims to identify the best practices that teachers have implemented in the online classes during the pandemic that facilitated students' online learning process. This article can help instructors and institutions improve classroom and online teaching beyond the pandemic situation.

1.2 Study Objectives and Research Questions

This paper focuses on these research questions:

- How has confinement affected students' academic performance?
- What has been the satisfaction of the students in relation to the teaching of the subject?
- Are there differences according to students' gender?

To empirically answer these questions and in order to provide insights in the training of engineers, this study presents two measurement instruments. Firstly, a quantitative analysis of the segmentation of the student's profile according to the degree of learning collected in a cross-sectional survey of a group with a non-probabilistic voluntary sample. Secondly, a quantitative comparison on the real learning of the students between the emergency situation and the previous situation; these are the final marks of six groups of classes that took the course in 2020 and 2021 compared to the final marks of four groups that took the course before confinement (2018–2019).

1.3 Context of the Study

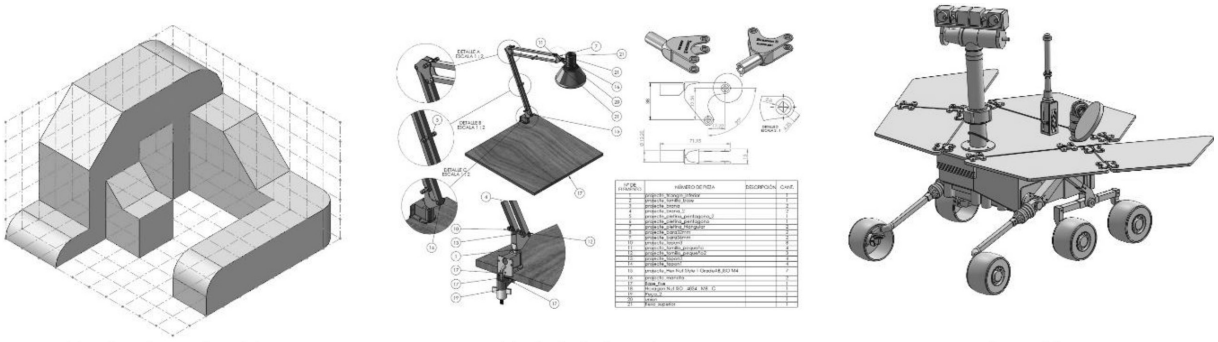
GE is a compulsory first-year subject, which carries six ETCS (European Credit Transfer System) credits. The subject is taught during the first and the second quarter with 14 sessions each quarter. The class groups, 24 in total, consisted of approximately 30 students in morning (M) or afternoon (A) sessions in all the degree courses (Electrical Engineering, Mechanics, Chemistry, Industrial Electronics, Biomedicine, Energy and Materials) at the Barcelona East School of Engineering (EEBE) from the Universitat Politècnica de Catalunya. UPC-BarcelonaTech (UPC) in Spain.

The challenge that the educational system has had to face to reinvent itself overnight in the distance mode has not been an easy task. New forms of pedagogy had to be accelerated, at the same time that much of online education was delivered in its most basic forms. There simply was not time to rethink pedagogy, work with new instructional designs, specially designed teaching materials for online training, and of course to train teachers to deliver online training. The confinement caused by the pandemic was applied from the third face-to-face class. Due to this, the learning methods had to be adapted to the online model using the Google Meet® tool for distance classes, different tutorials and problem-solving videos were created in a matter of weeks (with financial help from the institution to which the authors belong) and the teaching staff relied on pre-existing methodologies that the subject already had, such as a Virtual Classroom, online theoretical test and computer tools provided by the institution for distance sessions (Google Classroom®). The evaluation had to be agreed, modified and rethought to facilitate and make the availability of the students more flexible. The delivery times of evaluable individual works (Deliverables) and the times in which the exams were carried out were extended. Students with problems had the possibility of taking the exam on another day if they requested it.

The activities carried out (inside and outside the classroom) are diverse: theoretical learning through a self-assessment test, problem-solving with the use of solid modeling tools through computer-aided design (CAD) supported by videos, hand sketches elevation, and the elaboration of a final project in the group of an engineering set, among other activities. The learning of the subject is structured in three blocks (Theory, Laboratory and Project).

The Theory encourages individual responsibility and self-study activities for theoretical content outside of class time. In order to verify that the objectives set during the self-learning process have been met, the student is presented with 10 tests (of the 10 theoretical topics of the class) of multiple-choice self-assessment in the virtual classroom to be carried out in a voluntary and outside of school hours.

In the Laboratory it is modeled in 3D and the plans are made from an axonometric projection. Several (2 to 3) exercises are solved per class using the CAD Solidworks Education Edition 2020® tool. Each of the exercises are of great importance to understand and carry out the project that students must deliver at the end of the course. If the exercises are not completed in the classroom, students must deliver them in a short period of time. The level of complexity of the exercises increases throughout the course. Two aids are introduced to help the student to carry them out: Video exercises for the resolution of pieces and Tutorials from the tool itself.



Freehand part sketching | Exploded view plane | Assembly

Fig. 1. Examples of deliverables carried out by the students of the subject.

Finally, at the end of the classes, an original engineering Project is delivered that consists of a set of different mechanical components. The project content should include a short report, freehand drawings of the parts, printed plans with projections of each part, exploded views, specific movements, assemblies, and a video presentation of the project.

Fig. 1 shows examples of the different deliverables of work carried out by the students of the subject. It shows a freehand part sketching exercise, an exploded view plane, and a finished assembly.

The assessment of the autonomous learning generic competence is assigned to the subject GE [35] together with the specific competencies. This autonomous learning competence is acquired and assessed through the execution of different activities (theory and project) during the application of knowledge on standardization, technical drawing, and spatial geometry. The specific objectives of the subject can be seen at this link (https://tinyurl.com/ydz3egp7) (Spanish language). The complete study guide for students to follow all the academic activities of the course can be seen at this link (https://tinyurl.com/y7ygwh6h) (Catalan language).

2. Methodology

2.1 First Instrument: Quantitative Segmentation Analysis of the Student's Profile According to the Degree of Learning

A voluntary and anonymous online survey (https://tinyurl.com/buyo7rkx) (Spanish language) of a cross-sectional and analytical-descriptive type, mostly with closed questions, was sent. The Google Forms® form has been used among students who took the course from March to December 2020, that is, students from the second quarter of the 2019/20 academic year and the first quarter of the 2020/21 academic year. The objective of this survey was to know the opinion of the students about how they faced their studies in the confinement stage, their satisfaction with the subject and also with the new learning methods used. The survey was conducted on the last day of class (session 14) and was sent to a total of 810 students. With the data obtained, a descriptive and quantitative study was carried out analyzing the relationship of the different variables collected from the closed questions. The answers were first separated into four groups according to the degree of satisfaction with respect to "understanding and learning the contents of the subject" variable ("Strongly agree" = 4, "Agree" = 3, "Disagree" = 2, "Strongly disagree" = 1 and were compared with the rest of most significant variables of the study. In each of the groups, the mean and 95% confidence interval of each of the variables were calculated. The results are compared on a radar chart to determine the relationship between the variables and the degree of satisfaction. Since the collected variables are ordinal, the analysis is strengthened by calculating the Somers's D statistics to examine the association between them.

The survey asks about aspects related to the devices used to monitor the subject, the type of Internet connection and a list of the type of work software most used. It also asks about the problems that could have arisen from the confinement and if academic performance has been affected as a result of it. It also asks about the interest, learning and formative activities of the subject and finally about the evaluation methods and the difficulty and workload. Finally, and for the study, those variables that are believed to be most relevant for the research are extracted, with special attention to the variable "Understanding". Table 1 shows a global description of the questions posed and, in the central column, those variables that we believe are most significant for the study.

The results will be shown through radar charts (or spider diagrams). These diagrams display multivariable data in a two-dimensional chart revealing the relationships, trade-offs and comparative measures. Each radar chart is a plot that consists of a sequence of equiangular spokes, with each spoke representing one of the variables. All spokes start at

Table 1. Survey questions and most significant variables for the study

Related aspects	Most significant variables for the study	Survey questions
Initial aspects	Gender[1]	– Gender – Degree
Subject monitoring		– Subject tracking device during confinement – Type of Internet connection used – Work tools used to monitor the subject
Confinement and work	Attention[2] Computer_probl[2] Resource_probl[2] Internet_probl[2] Health_probl[2] Acad_perform[2] Workplace[2] Time_spend[2]	– Attention to emails and documentation sent – Computer problems – Problems accessing all available resources – Problems to follow the classes normally – Health problems that have prevented tasks from being carried out normally – Affecting academic performance – Work space conditions – Time dedicated to study
Interest, learning and training activities in the subject	**Understanding[2]** Tutorials[3] Videos[3] Tests[3] Project[3] Active_work[2]	**– Understanding and learning the contents of the subject** – Usefulness of training activities: Tutorials Videos Tests Project – Carrying out virtual activities
Workload during confinement	Workload[4] Comp_difficulty[5] General_difficulty[5]	– Workload – Difficulty compared to other subjects – General difficulty
Evaluation methods	Adapt_Eval[2] Useful_Eval[2] Fair_Eval[2]	– Adaptability of evaluation methods – Usefulness of evaluation methods – Fairness of evaluation methods
Open field question		– Global assessment

[1] "Male, Female"
[2] "Strongly agree" = 4, "Agree" = 3, "Disagree" = 2, "Strongly disagree" = 1
[3] "Very useful" = 4, "Useful" = 3, "Little useful" = 2, "Very little useful" = 1
[4] "Very large" = 4, "Large" = 3, "Small" = 2, "Very small" = 1
[5] "Very difficult" = 4, "Difficult" = 3, "Easy" = 2, "Very easy" = 1

the same point representing a value equal to zero and each circumference indicates an increment of 1 in the measure in each variable. In each spoke it is drawn a point which represents the mean of the answers, besides the 95% confidence interval is represented by a straight line over the spoke. This interval gives us information about the variability of the response: the longer the line, the more variability the variable has.

The survey finally asked the students (with an open field response) a global assessment of their learning process during confinement. To perform the qualitative analysis of the responses, the constant comparison technique was used. It is necessary to clearly code each different reason given in the responses and to identify when an answer refers to each reason. An abductive methodology was used to define these motives. Table 2 shows the most important design aspects of the survey.

2.2 Second Instrument: Quantitative Comparison of Student Learning before and during Confinement

The evaluation of the subject (before 2020) consisted of seven pre-established tests set on weeks 5, 9, 10 and 14 of the academic year. Two of these tests were theoretical (TTN and TTG), four practical (CAD1, CAD2, CAD3 and PCA) and a final delivery of the group project (Proj). In the first month of lockdown (April 2020) the new evaluation system was agreed among all the teaching staff who taught the subject. CAD1 and PCA were eliminated and replaced by the delivery of individual works (Deliverables), facilitating the deliveries in quite

Table 2. Most important design aspects of the survey

Survey	Description
Type of survey	Transversal
Population	One-year students of the subject GE
Confidence interval	95%
Sampling error	0.02%
Survey period	March to December 2020
Sample	810 students (answers 264, 32%). Voluntary non-probabilistic
Process	Anonymous online
Data collection instruments	Google Forms®
Data analysis instruments	R Studio®

Table 3. Comparison of the final marks of the subject, before and during confinement

Final mark of the subject				
	Normal period – Before 2020		Pandemic period – 2020, 2021	
Week	Partial mark	Mark weight	Partial mark	Mark weight
5	CAD1	10%		
9	PCA	10%	Deliverable 1	15%
10	CAD2 / TTN	25% / 15%	CAD2	25%
11			TTN	15%
13			Deliverable 2	5%
14	CAD3 / TTG / Proj	15% / 10 % / 15%	CAD3 / TTG / Proj	15% / 10% / 15%

long periods of time with an increase in flexibility in the standards of the didactic guide. Table 3 shows the changes produced in the evaluation before and during confinement.

Where: TTN = Drawing norms self-assessment test; TTG = Self-assessment spatial geometry test; CAD1 = 1st Mid-term exam; CAD2 = 2nd Mid-term exam; CAD3 = 3rd Partial exam spatial geometry; PCA = Mid-term sketching and adjustments; Proj = Project; Deliverables = Delivery of class exercises.

In addition to the final mark of the subject, each student receives a final mark for the autonomous learning competence that is added to their academic record. It is the sum of two components of the Final Mark: two components related to the theory (TTN, TTG) and the project (Proj.), where: Final Mark for the Autonomous Learning Competence = 0.75xProj + 0.25xTheory.

In this study, a quantitative comparison of the average final marks of the subject and the average final marks for the autonomous learning of the subject during the pandemic period and the period prior to the pandemic was made. The results and discussion of these findings can be found in sections 3 and 4. Table 4 shows a summary of the different groups in which marks are compared (pre-pandemic and pandemic) along with the number of students and the teaching period.

3. Results

3.1 Results Of The Quantitative Segmentation Analysis of the Student's Profile According to the Degree of Learning

The survey was answered by 264 students (32% of the total number). Among them, 74.6% of the students affirmed to follow the classes during the confinement with a laptop and 23.1% with a desktop computer. The remaining 2.3% did so with a mobile phone or tablet. Regarding the Internet connection, 82.6% of the students used fiber optics and 11% ADSL. The rest of students was divided between public Wi-Fi and mobile data.

The mean responses of the students and their variability have been analyzed according to the degree of learning and understanding of the contents of the subject (''Understanding'' variable). From the 264 responses received, 17% of the students consider they strongly agree with having learned and understood the contents of the subject, 60% agree, 19% disagree and 4% strongly disagree. See Fig. 2a.

A comparison of the degree of learning and understanding of the contents of the subject disaggregated by gender was also made. From the responses obtained, 33% corresponded to women. This proportion is in accordance with the proportion of women enrolled in the subject. With respect

Table 4. Summary of the different class groups

Normal period (2018–2019)			Pandemic period (2020)			Pandemic period (2021)		
Groups	Number of students	Teaching period of the subject	Groups	Number of students	Teaching period of the subject	Groups	Number of students	Teaching period of the subject
M22	19	February to May 2018	M22	25	February to May 2020	T12	30	February to May 2021
A31	28	September to December 2018	M61	29	September to December 2020	M21	21	February to May 2021
A92	22	February to May 2019	M51	29	September to December 2020	M31	18	February to May 2021
A22	24	September to December 2019						

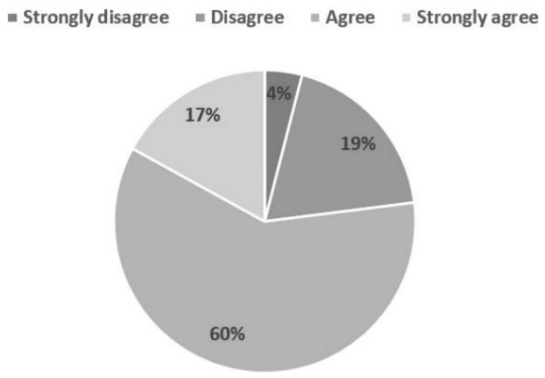


Fig. 2a. Degree of learning and understanding of the contents of the subject.

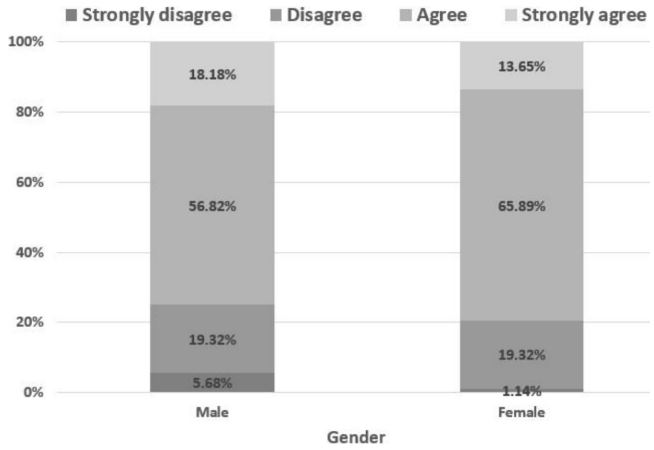


Fig. 2b. Degree of learning and understanding of the contents of the subject disaggregated by gender.

to women, 79.54% (65.89% + 13.65%) agree or strongly agree with having learned and understood the contents of the subject. With respect to men, 75% (56.82% + 18.18%) also agree or strongly agree with the learning of the subject. See Fig. 2b.

Fig. 3d (Strongly disagree), the one which displays the profile of the students who consider that they have not learned neither understood the contents of the subject, corresponds to 4% from Fig. 2a. It can be seen that this profile has high variability in the answers, except on the evaluation aspects (Adapt_eval variable and useful_eval variable), where their values are close to 1 (Strongly disagree). These high variabilities encourage us to ignore their answers. On the opposite side, in the other three cases (Fig. 3.A. Strongly agree, B. Agree and C. Disagree) the variability is very small, so these profiles can be considered as reliable. A clear and direct relationship is observed between the degree of learning and variables such as: attention to emails and documentation sent, the conditions of the workspace and the hours dedicated to studies. For example, with greater attention to emails and notifications from teachers, learning and satisfaction with the subject improve. On the other hand, the inverse relationship between the degree of learning and problems or difficulties (computer problems, health, access to resources, etc.) is revealed. Finally, the Somer's *D* statistics report (see Fig. 4) shows the highest association or correlation between the degree of learning and the evaluation methods, the project, and the conditions of the workplace. In the opposite, the lowest and inverse association with the degree of learning is given by difficulties and workload.

In the radar charts of Fig. 5, the profiles of the students can be observed according to the degree of learning and gender. The relationships are maintained, but it is observed that, with respect to men, women value almost all the variables with greater satisfaction. In section 4 these results obtained are discussed.

The survey finally asked the students (with an open field response) a global assessment of their learning process during confinement. Some of the most important reasons expressed by the respondents were identified, among which are the availability of having the classes recorded, the consultations based on ''Share screen'' with the students during the class to answer individual questions, the quick responses by mail, and individual tutorials through the Google Meet® tool.

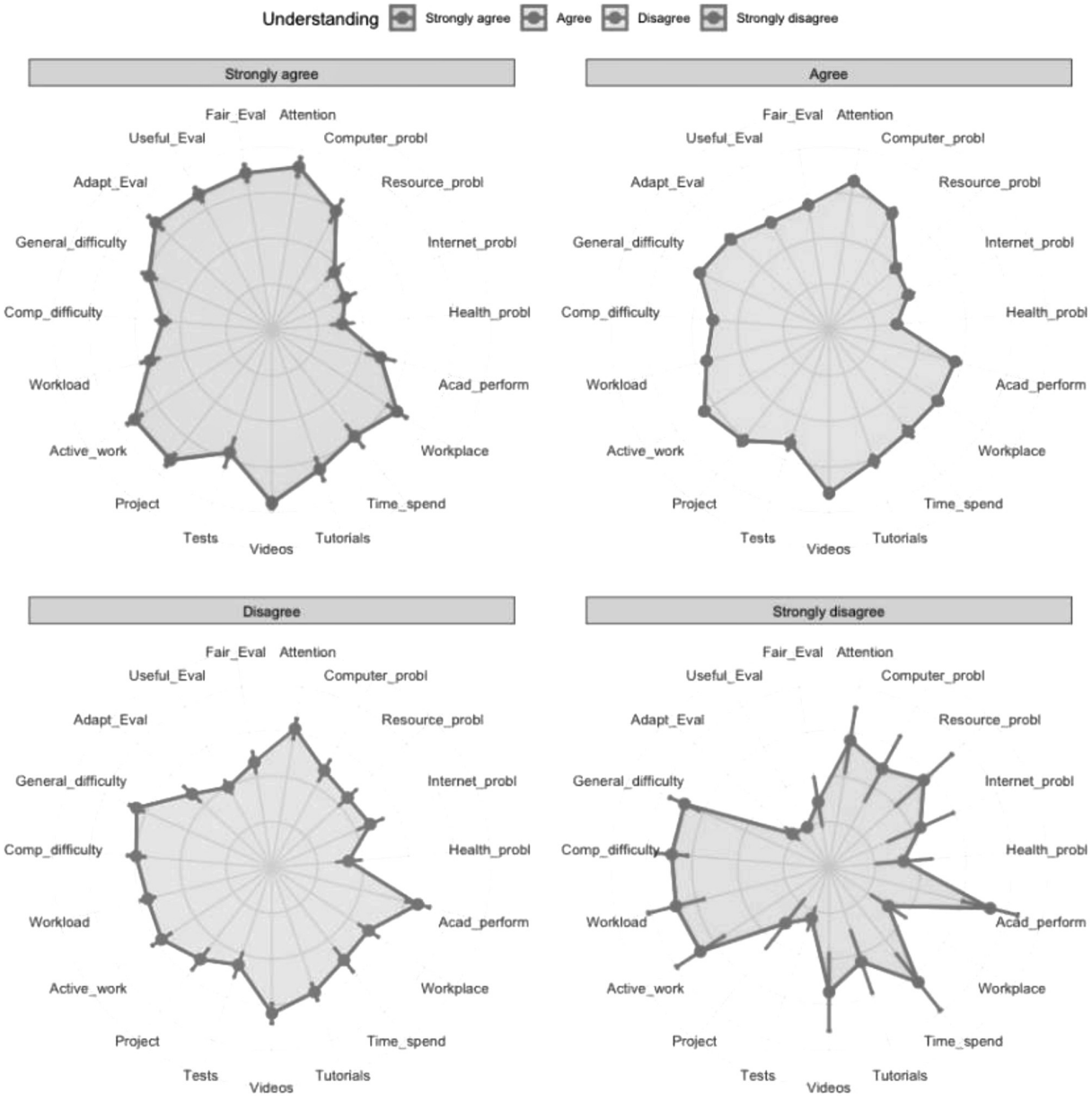


Fig. 3. Radar charts corresponding to ''Understanding'' variable (A. Strongly agree (44 students), B. Agree (158 students), C. Disagree (51 students), D. Strongly disagree (11 students)).

Some of the opinions of the students about the subject and the teachers are collected: *''Explain the contents of the subject well (sometimes very quickly)''* . . . *''The organization and the examination system have been the best of all the subjects''* . . . *''The classes are not monotonous and boring, there is interaction between the teacher and the students which is very good''* . . . *''The way he addresses the students''* . . . *''A different assessment should have been proposed, giving more importance to the project, and even a couple of projects could have been carried out throughout the quarter with the intention of dividing the mark between them and not giving as much weight to the exams, since the projects tend to motivate more to do things that students like to model with SolidWorks ''*. . . *''Although this subject has taken me a long time, it has helped me to do all the tutorials and tests because it has been very good for me''*.

At the end of the academic year, in the usual meetings of the group of professors of the subject, some aspects related to the workload in these exceptional conditions were discussed. In relation to the volume of work dedicated to virtual teaching by teachers compared to face-to-face teaching in the normal situation, the vast majority of teachers of the GE subject stated that the increase in time spent was 100% or even more. The number of hours

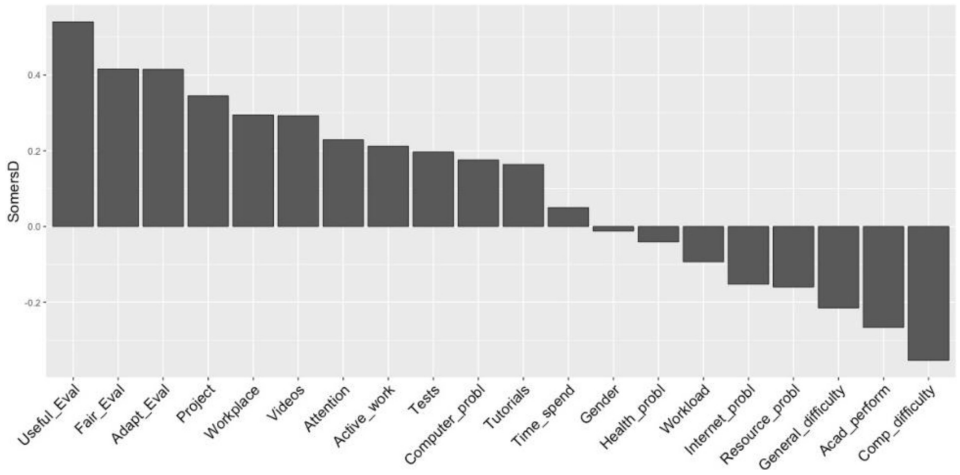


Fig. 4. Somer's *D* statistics between "Understanding" variable and the rest of variables.

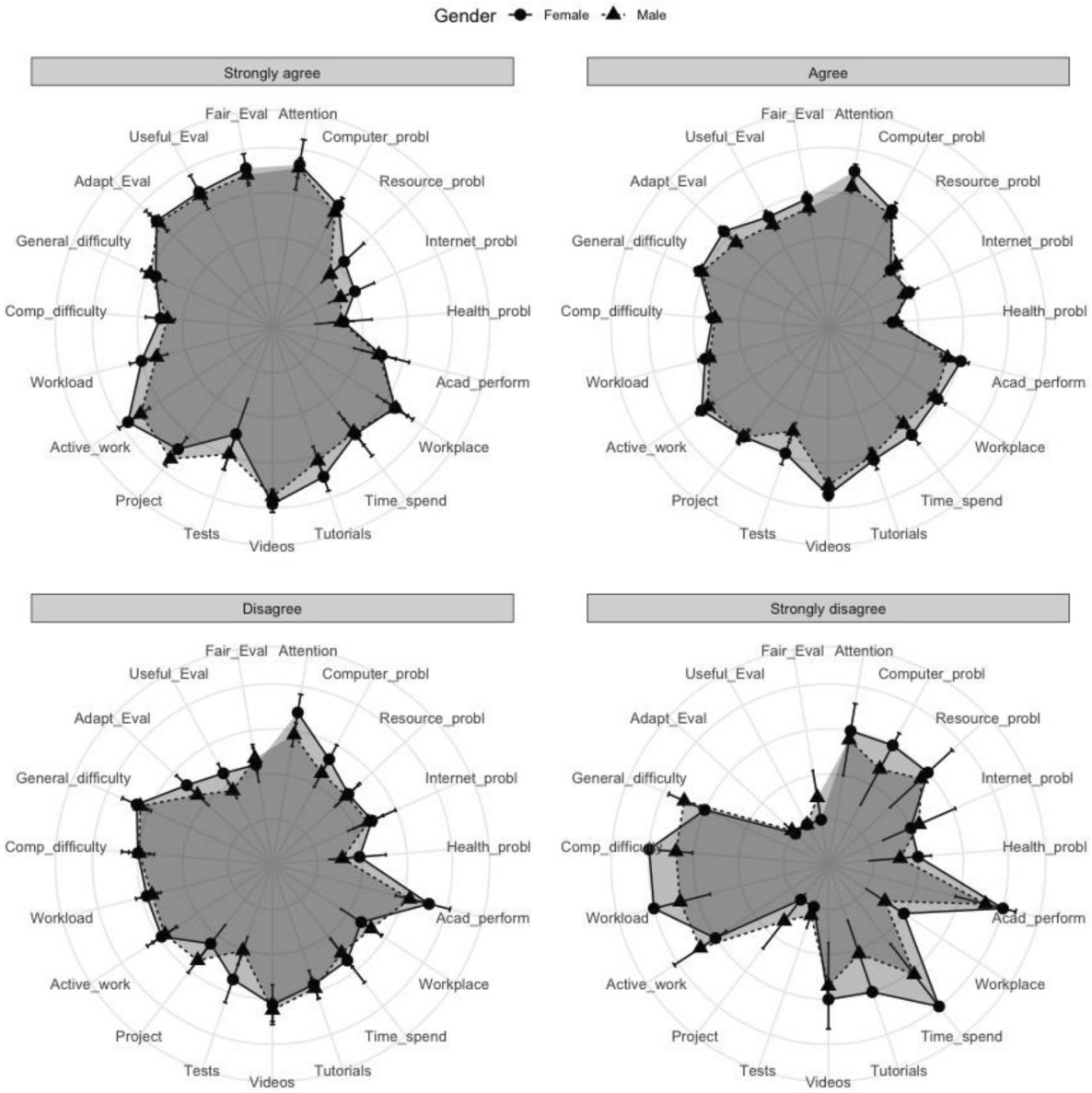


Fig. 5. Radar charts corresponding to "Understanding" variable disaggregated by gender (A. Strongly agree (32 men – 12 women), B. Agree (100 men – 58 women), C. Disagree (34 men – 17 women), D. Strongly disagree (10 men – 1 women)).

devoted to student consultations by email and/or videoconference was one of the most worrying aspects. Regarding the increase in e-mail inquiries in this period of non-face-to-face teaching, they stated that they had increased between 50% and 100% or even more. All agreed that the hours spent on videoconferencing student consultations had increased by at least 3 hours per week compared to face-to-face consultations.

3.2 Results of the Analysis of the Average Marks of the Different Class Groups

Table 5 shows the average and the standard deviation for the final marks of the subject and for the final marks of the autonomous learning competence for the GE subject of six groups of classes from the pandemic period (2020, 2021) compared to four groups of classes from the 2018–2019 period (pre-pandemic). This table highlights aspects such as the number of students who passed the course, the number of students who failed and those who dropped out.

According to the Shapiro-Wilk test, final marks and autonomous learning competence final marks do not come from normal distributions. Therefore, to contrast whether the average of the marks of the pandemic period (2020) have increased with respect to the pre-pandemic period (2018–2019) and pandemic period (2021), the unpaired two-samples Wilcoxon test (also known as Wilcoxon rank sum test or Mann-Whitney test) was conducted. Results show that the average of the pandemic period final marks (2020) is significantly greater than the average of the pre-pandemic period final marks (2018–2019) with a p-value = 0.0004385. In the same way, the average of the pandemic period final marks (2021) is significantly less than the average of the pandemic period final marks (2020) with a p-value = 3.998e-08. In other words, marks returned to drop even more than the pre-pandemic period (with a p-value = 0.003177). Autonomous learning competence final marks follow the same pattern with similar p-values (p-value = 0.004061, p-value = 8.176e-11, and p-value = 1.007e-07, respectively).

4. Discussion

Some experiences related to the classes given and an overall assessment of the impressions of the teachers who taught the subject during the lockdown are discussed below. Online class attendance was close to 100% in most groups, unlike in previous years where class attendance was not as high. The high number of students who attended the online classes suggests the need for communion between the student and the teaching staff. Studies show that the feeling of isolation worsens significantly as confinement time increases. Therefore, it is necessary to implement adequate contact mechanisms between students and teachers in online educational systems, as explained in the Introduction section [13, 14]. The low academic dropout rate of students during the pandemic also stands out. Table 5 shows the low number of students who dropped out of the

Table 5. Average and standard deviation of the final marks and of the final marks of the autonomous learning competence for the GE subject of six class groups from the pandemic period (2020, 2021) compared to four class groups from the pre-pandemic period (2018, 2019)

	Year - Quarter									
Situation	**Normal period (2018–2019)**				**Pandemic period (2020)**			**Pandemic period (2021)**		
Group	**M22**	**A31**	**A92**	**A22**	**M22**	**M51**	**M61**	**T12**	**M21**	**M31**
Date	2018 – 1Q	2018 – 2Q	2019 – 1Q	2019 – 2Q	2020 – 1Q	2020 – 2Q	2020 – 2Q	2021 – 1Q	2021 – 1Q	2021 – 1Q
Number of students who passed the course	12	23	17	15	21	27	27	13	14	6
Number of students who failed	5	5	3	7	3	2	2	6	5	9
Number of students who dropped out	2	0	2	2	1	0	0	11	2	3
Average final mark	**5.2**	**6**	**6.2**	**5.2**	**6.6**	**6.4**	**6.8**	**5.3**	**4.8**	**4.4**
Average final mark of the autonomous learning competence	**5.3**	**6.3**	**6.5**	**6.1**	**6.6**	**6.5**	**6.9**	**5.3**	**4.4**	**4**
Standard deviation final mark	**1.295893**	**1.662005**	**2.119453**	**1.620305**	**2.121167**	**1.234181**	**1.662629**	**1.204257**	**1.758621**	**1.534585**
Standard deviation final mark per period	**1.737668**				**1.684281**			**1.521212**		
Standard deviation of the autonomous learning competence final mark	**0.6479606**	**0.827024**	**1.849459**	**1.166821**	**1.959476**	**1.74368**	**1.343897**	**1.861961**	**1.907097**	**1.820387**
Standard deviation of the autonomous learning competence final mark per period	**1.357782**				**1.663129**			**1.900846**		

course compared to previous years, as well as the suspended students that decreased significantly, especially in 2020. Female student intervention and participation in classes during confinement (with the Google Meet® video tool) increased markedly. A fact that was perceived and surprised was the large number of interventions and questions on didactic topics made by the female students. They constitute between 25 and 30% of the students enrolled in the GE course. It contrasts with the low interventions of students in face-to-face classes and differs from Khalil et al. [12] who points out that issues related to the implementation and quality of online courses can become barriers to participation and the acquisition of knowledge.

During the last academic year corresponding to the February-May 2021 period, most of the classes continued to be developed virtually (some, at the request of the school, were done in person). The same communication tools between teachers and students continued to be used in a similar way as had been done previously, although some teachers reported problems with the use of digital whiteboards (very necessary for the development of the subject). The number of deliverables (class exercises and projects) to be corrected was very high, notably increasing the workload of teachers. The uncertainty caused by the continuous changes in government policies regarding the prevention of the disease did not improve the mood of teachers and students. The experience acquired by teachers in virtual teaching during these last semesters has not made the teaching-learning process more fluid. It has been just as complicated as the previous quarter as the time of confinement progressed. It has been perceived that during the last academic year (February-May 2021) the face-to-face classes had a lower attendance than the virtual ones. Anyway, the latter were very difficult to verify beyond the fact of being connected. The students, accustomed to the inertia of many years of presence, have not managed to get used to these new teaching experiences implemented in such an abrupt and global way. They have enrolled in our university, which is a face-to-face university, where physical presence for most of the activities is essential, and the fact that it cannot be carried out causes discouragement and unease that is difficult to quantify. It is urgent to return to the previous face-to-face system because this model is not sustainable over time beyond an emergency situation.

4.1 Discussion of the Results of the Quantitative Segmentation Analysis of the Student Profile According to the Degree of Learning

In relation to this section, the results obtained show that the students who have been most satisfied with the subject are the ones who best value the evaluations and non-contact activities; they are also the ones who have worked the most, have dedicated more time to it and have had fewer problems in the development of academic activities. The responses with one of the highest ratings have been when the question was "I have carried out the non-contact activities (tutorials, evaluation test, etc.) that have been indicated to me", which shows us a high involvement of the students in carrying out the activities that the teaching staff has commissioned. Carrying out the Project as a training activity has received an assessment above the average and it has been very useful that the class exercises are solved on video. The good conditions of the workspace have been very important to assess their satisfaction with the subject. For most of the students who have taken the subject, in general, the entire academic year has seemed difficult, perhaps motivated by the adaptation of all teaching to the situation caused by the pandemic. When asked about the difficulty of the GE subject compared to others, students state that it has not been difficult (or less difficult than the other subjects he has taken) as is the case with the workload. So, this study highlights the online course's quality as a significant factor in students' satisfaction and learning, as it is shown in Piccoli et al. [5], Sun et al. [6], Ibrahim et al. [7], Aristovnik et al. [8] and Khalil et al. [12]. Moreover, as in Puljak et al. [23], the assessment methods and materials used in classes during the health crisis are tailored to e-learning and students are satisfied with the different aspects of online teaching, such as the content, classes, and teacher support, as Jacques et al. [13] and Rodríguez-Rodríguez et al. [22] report. In this research it is shown that interactions with fellow students and teachers are essential for students' satisfaction and play a decisive role in academic development and students' achievement, which coincides with the results from Mcinnerney [29], Arbaugh [27] and Hong [28]. The scientific literature reports that lack of contact can worsen the educational experience [36–32]. Regarding the discussion in relation to the responses of the students disaggregated by gender, in general, it is observed that the woman gives a little more value to all the variables studied, although it is observed that their responses have more variability than men, but not in a very clear and decisive way. These differences are not significant and consistent and it opens the door to new studies that provide empirical evidence that helps to understand the impact of online teaching during the pandemic on men and women from different countries and academic fields.

4.2 Discussion of the Results of the Average Marks of the Different Class Groups

According to Jacques et al. [13] this study shows that student marks not only do not decrease, but also increase significantly in the first period of the pandemic (2020) and are similar to or better than those expected in face-to-face teaching, but the following period of the pandemic (2021) the marks were maintained or even decreased with respect to the normal period. The drop in marks in 2021 may be due to fatigue, stress, anxiety or lack of motivation of the students as the period of lockdown lengthened. The literature highlights studies where students obtained worse results since face-to-face classes were canceled [11]. Therefore, the findings shown cannot be validated and further research is required as there is no reliable consensus yet on student performance and achievement during confinement. Regarding the academic performance of the students in the GE subject, the teachers were generous because the circumstances were exceptional and they were aware that the external conditions imposed should not be passed on to the students. Students had many advantages and possibilities to turn in assignments and tests in a timely manner. Teachers were considerate of troubled students. They had to deal not only with academic difficulties, but also personal ones, such as being locked up at home and, in some cases, with infected or deceased relatives. There is consensus in international research that repetitions do not help the student's progress, quite the contrary. They generate a disruption that accumulates and, in the medium term, makes students perform worse and drop out more [37]. In any case, it is difficult to draw conclusions about academic performance since, as mentioned, due to the pandemic the assessment of the subject had to be modified to make it more flexible to the availability of the students. This makes the marks obtained from the groups not really comparable.

4.3 Best Practices Beyond the Lockdown

During the teaching of the classes in the confinement, a series of actions or good practices that could be implemented in the coming years have been evidenced and identified. They are practices that could be implemented without the need for great resources and could be applied to both online and face-to-face training. These provide interesting actions and methodologies that can be applied to improve teaching in engineering studies beyond the pandemic situation and that would help improve the training of students:

- Quick feedback and communication: The feeling of loneliness and isolation caused by the confinement has become evident. Through the surveys, the students highly valued the follow-up and the speed with which the teachers responded to their doubts and questions via email. Although it is true that many students abused this communication channel, it generated in them a feeling of support and attention from the teachers. Also, the quick feedback on the return of midterm grades was very welcome. In general, it is a well-valued practice, both in person and remotely, and has been fully verified in the scientific literature [38, 39]. Some research has already highlighted the importance for teachers of receiving feedback from students in order to improve teaching [40], however, the results of this study suggest that the benefits of the feedback are bidirectional, and it is not only helpful for teachers, but also makes students feel heard and valued.
- Record the classes with the Google Meet® tool: Recording the classes to see them again asynchronously and share exercises that have already been solved is a methodology that the students have valued positively and that is emerging as a resource to be implemented in the next years. They use them as a review of the classes they were unable to attend and as a reinforcement for understanding the different topics.
- Support video tutorials: The incorporation of tutorials and support videos of the exercises solved in class has been very important and well valued by the students. Other research demonstrates the quality of these practices [41].
- Reduction in the number of students per class: It is considered a priority to reduce the number of students in classes. An OECD report [42] warns of the request of teachers to reduce the number of classes in Spanish universities. This action would result in faster feedback and closer communication with students, as well as improving the quality of instruction.
- Offer high-quality continuous training: As education professionals, their responsibility is maximum with the generations that are in the process of learning and preparing to be citizens who can competently play a role in the future. The pandemic has shown that teachers need continuous training, they are forced to review their methods, their educational practice and adjust it to the group they are addressing. This, in reality, is a constant in the teaching profile: recycling, revision, unlearning and re-learning or adaptation [43].
- Instant messaging: Students positively value opening communication channels faster than emails, such as WhatsApp or Telegram groups, to communicate with other students and teachers. Previous research indicates that communication between students and teachers can be

more complicated in distance learning than in traditional learning [44–46], so this offers them a method of communication closer and in which they feel that doubts can be answered more quickly.

- Small workgroups: Carrying out group work with other classmates is highly valued since students have felt isolated during the COVID-19 experience, and it is a way of connecting with their classmates. However, managing groups that are too large from distance learning is complex, so it is advisable to limit the groups to 2–3 students.
- Individualized tutoring sessions: Students positively value having query sessions with teachers to express their doubts individually or in small groups. As other studies indicated [47], some students find it challenging to communicate with the teachers during remote learning and raise their doubts during a videoconference class. These individualized tutoring sessions can provide them with a safe environment where they feel more secure in consulting their doubts.

5. Conclusions

In this study, the impact of confinement and distance classes on the learning of the GE subject in engineering students is analyzed. In the first place, through a survey, the students' perception of their academic development has been analyzed and, secondly, their academic qualification has been compared with the qualifications obtained in the pre-pandemic period with face-to-face teaching. It is found that academic development has not been affected during the pandemic, which can be explained by the rapid and efficient intervention of the teaching staff to remodel the teaching content and reorient teaching towards a non-face-to-face model. This includes the quality of the classes, the adequacy of teaching to the online format, the teaching material available to students, adaptation of the evaluation model, contact with fellow students and teachers, etc. These practices can be considered good practices and be implemented both in other subjects with online teaching and in subjects with face-to-face teaching, beyond the pandemic period.

The results of this study should be interpreted in the context of some limitations, which may be addressed in future research. Participants in this research were recruited from a specific subject and specific engineering degrees, so the results may not be extrapolated to all engineering studies. As the field of engineering is wide and there are many different specializations, it would be interesting to expand the study and validate the results in other engineering subjects and degrees. In the same way, it would also be interesting to extend the study to other universities and countries since the impact of the COVID-19 pandemic has not been the same everywhere.

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