U.Porto Journal of Engineering, 9:4 (2023) 71-96
ISSN 2183-6493
DOI: 10.24840/2183-6493_009-004_001625

Received: 30 May, 2022
Revised: 14 November, 2022
Published: 22 September, 2023

Students' perceptions of higher education courses and instructors before and during Covid-19: the case of the Industrial Engineering and Management degree at the University of Porto

Marta Campos Ferreira[1,2], António Ramos Silva[3,4], Ana Santos Camanho[1]

[1]Departmento de Engenharia e Gestão Industrial, Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 PORTO, Portugal (mferreira@fe.up.pt; acamanho@fe.up.pt) ORCID MCF: 0000-0001-9505-5730 ORCID ASC: 0000-0001-7683-5889
[2]INESC TEC, Rua Dr. Roberto Frias, 4200-465 PORTO, Portugal
[3]Departmento de Engenharia Mecânica, Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 PORTO, Portugal (ars@fe.up.pt) ORCID: 0000-0002-4146-6224
[4]INEGI, Campus da FEUP, Rua Dr. Roberto Frias, 4200-465 PORTO, Portugal

Abstract
The recognition of Covid-19 as a global pandemic in March 2020 forced the closure of schools and universities around the world, raising the need to adopt emergency teaching methods. A year and a half later, the situation is still not resolved, but there is more data that allow us to understand the real impact. This study presents a comprehensive analysis of higher education students perceptions about courses and faculty during the last 5 years (2016-2021), with a special focus on the differences in perception between the pre-Covid-19 and the during Covid-19 phases. To this end, the pedagogical surveys that are answered by students from an engineering degree at a Portuguese university at the end of the first and second semester of the academic year are analyzed. The results allow us to identify two distinct moments in the Covid-19 phase: a first in which feelings of positivism and appreciation of students for the instructors and the courses they teach stand out, and a second moment in which students become more demanding and dissatisfied with the courses and with the instructors, leading to a lack of motivation and involvement of students.

Author Keywords. Emergency Remote Teaching, Online Learning, Mixed Learning, Pandemic.

Type: Research Article

Introduction

In December 2019, an increasing number of cases of the new coronavirus (SARS-CoV-2) were identified in the city of Wuhan, China (Li et al. 2020). The contagion rate has happened at unprecedented speed, with the World Health Organization (WHO) declaring a Public Health Emergency of International Concern on 30 January 2020 and a pandemic on 11 March 2020 (WHO 2020).

Countries around the world were forced to take urgent and drastic measures in order to stop the spread of COVID-19 among people. Schools closed and face-to-face (F2F) teaching methods were replaced by remote teaching methods (UNESCO 2020). It was an unplanned and emergency transition, accentuating the differences between countries and people. In

April 2020, the closing of schools affected about 89.4% of the total enrolled learners (Marioni G. 2020). One year after the start of the COVID-19 pandemic, nearly half of the world's students are still affected by the partial or complete closure of schools, and more than 100 million additional children will fall below the minimum level of reading proficiency (UNESCO 2020).

Higher education was no exception. A Global Survey conducted by the International Association of Universities between March 25 and April 17, 2020, shows that two thirds reported that classroom teaching has been replaced by online teaching and one quarter that learning activities are suspended, but the institution is working on alternative solutions to continue teaching and learning, through digital or self-study means (Marioni G. 2020). The adoption of distance learning methodologies was already a reality in higher education institutions (Hiltz & Turoff 2005; Keengwe & Kidd 2010; Robinson & Hullinger 2008; WALLACE 2003). However, the pandemic accelerated the transition process and, although there were some institutions prepared for this digital transition, others were not, bringing numerous challenges.

This emergency transition, caused by the COVID-19 pandemic, is beginning to be studied by researchers around the world, namely on the challenges and opportunities of emergency remote learning (Adedoyin & Soykan 2020; Dhawan 2020) and its effectiveness (Chaudhry et al. 2021); adaptation of teachers (Karadag et al. 2021) and students to online instruction (Ives, 2021); teaching strategies adopted and inequalities in university courses (Gillis & Krull 2020); empirical studies on the experiences of students and faculty in this new teaching context (Oliveira et al. 2021). However, most of these studies are exploratory in nature, covering very small samples and very specific contexts. Additional investigation is needed with more rigorous methods and with larger samples, and it is essential to understand this emergency transition not only from the instructors' point of view, but also, and especially, from the students' perspective (Gillis & Krull 2020).

This study contributes to the understanding of the phenomenon of Emergency Remote Teaching (ERT) in higher education, through the analysis of students' perceptions about the courses and instructors. To this end, the results of pedagogical surveys of the last five years (2016 to 2021) of the Industrial Engineering and Management degree of the Faculty of Engineering of the University of Porto, Portugal, were analyzed. A comparison of survey results before and during the pandemic was carried out, allowing us to understand how students' perceptions on courses and faculty have evolved over the years and how they have adapted to the new reality of ERT.

This paper is organized as follows: the next section presents the literature review. Section 3 details the methods and the data used in this analysis. Section 4 presents the main results that are discussed in section 5. Finally, section 6 presents the main conclusions of this study.

1. Literature Review

With the closing of schools due to the COVID-19 pandemic, F2F learning was replaced by online education. However, there are several authors who argue that the concept of online learning (OL) known until then cannot be applied to the state of emergency caused by the pandemic, and should be replaced by ERT (Charlges et al. 2020) (Mohmmed et al. 2020). Unlike OL, where courses are planned and designed to be effectively delivered online, ERT involves "exploring the available remote learning tools to deliver curriculum or educational materials that would normally be delivered physically or as hybrid or blended courses" (Mohmmed et al. 2020).

Thus, in contrast to OL where courses are planned from the beginning to be online, ERT involves a temporary adaptation of courses so that students have access to education in an alternative way to F2F, hoping that at the end of the emergency situation everything returns to normal (Charlges et al. 2020). Somewhat similar situations can be those in which educational physical infrastructure was severely affected, such as the Hurricane Katrina (Gardner et al. 2007) or the Syrian war (Hos 2016). Although in the case of COVID-19 the physical infrastructure was not affected, there was a break with traditional teaching and a migration of learning methods. This migration from F2F to ERT brought many challenges and opportunities.

One of the results of a distance learning experience is the lack of direct interaction between faculty and students and among students (Ferri et al. 2020)**.** Asynchronous teaching methods, despite making the learning process more flexible, do not allow for direct and real-time interaction between the teacher and the students. On the other hand, it is described that even in case of synchronous methods, students avoid turning on the cameras, lacking direct and visual contact (Oliveira et al. 2021) and leading to a delay in responses and feedback (Petrides, 2002). However, this effect described in the OL literature does not seem to apply in ERT, as instructors demonstrated greater flexibility and willingness to virtually meet with students, answer questions and give feedback (Oliveira et al. 2021).

Another challenge of remote teaching methods is the fact that they are very dependent on technological devices and the internet. During classes there may be connectivity problems, aggravated by the increased number of users in a household, and lack of available technological devices. This problem is intensified for students with less access to economic resources, whose access to personal computers and the internet is more limited (Clark & Gorski, 2014). This type of situation increases social inequalities, namely in terms of access to education (Hargittai, 2003). The use of technological means in teaching raises another question regarding the ability of instructors to use new technologies and teaching tools, without prior training or adaptation (Lee & Jung 2021). This is indeed a challenge for people who are not digital natives, at the risk of a poor teaching-learning experience (Adedoyin & Soykan 2020).

The compatibility of applying distance learning methodologies to courses that require a considerable experimental component, such as sports science, engineering or medical science, is also questionable (Adedoyin & Soykan 2020). Effective and efficient online teaching may not be possible in these types of subjects that require hands-on experience in laboratories or real field (Mohmmed et al. 2020). At the same time, the ERT raised serious questions regarding student assessment. Some argued that the grading system should be modified as students are not getting the same experience and teaching opportunity as in F2F (Adedoyin & Soykan 2020). On the other hand, the easy and quick access to content by the students and the ease of communication between them, made the instructors adopt tighter assessment strategies, such as reducing response times and not allowing for reviewing the responses given during an exam. The measures implemented to try to prevent fraud often collided with the interests of students who considered them excessive and unfair (Oliveira et al. 2021).

Additionally, all this quick and unexpected transition to ERT has resulted in excessive work for institutions and instructors who had to adapt and transform F2F courses content for online platforms, increasing the load of stress (Adedoyin & Soykan 2020). Finally, the entire pandemic situation caused increased stress levels for instructors and students, who had to work overtime, not only to meet school demands but also to support domestic and family tasks (Gillis & Krull 2020). This excessive workload and the climate of uncertainty in terms of health and finances have mental health impacts yet to be explored (Xiao et al. 2020).

It is clear that OL has advantages, such as convenience (Mohmmed et al. 2020), flexibility (Keengwe & Kidd 2010) and self-paced (WALLACE 2003), making the pandemic an opportunity for digital transformation in education in general, and in higher education in particular. Studies like the one reported in this paper can help clarify what worked well or poorly during the pandemic, and contribute to improving pedagogical best practices.

2. Methods and Data

This section presents the methods and data used in this work, and is organized according to the following sub-sections: background, participants, instrument and data analysis.

2.1. Background

This study aims to examine the higher education students' perceptions of courses and instructors during the COVID-19 pandemic. To this purpose, we rely on the case study of the Faculty of Engineering of the University of Porto (FEUP). In this university, pedagogical surveys are applied to students twice a year, and the results of the questionnaires from the last 5 years (2016-2021) were analyzed. The study comprises a sample of all courses (n=49) of the integrated Master's degree in Industrial Engineering and Management (MIEGI) from FEUP. This is a 5-year program, combining a Bachelor degree (first 3 years) and a Master's degree (last 2 years). It is a multidisciplinary degree since it includes courses from different fields of science, technology and management. It should also be noted that University of Porto is a leading university in Portugal, regularly in the top 300 in the QS World University Rankings. This degree in particular - MIEGI – has been in the top 5 degrees with the highest entry grade at a national level, meaning that it is among the most sought after programs in Portugal, thus attracting the best students.

Table 1 shows the distribution of courses by year of MIEGI study plan. Analyzing it, we see that the first three years have a stronger component of mathematics, engineering and information technology, and the last two have a stronger component of business and operations management. The subjects are taught through theoretical, practical and also laboratory classes, constituting a very rich and diverse setting for this study. Each academic year consists of two semesters: the first semester begins in September and ends in February of the following year, and the second semester begins in March and ends in July.

Year	1ST Semester	2ND Semester
1	Computer Programming I Industrial Drawing Project FEUP Mathematical Analysis I Linear Algebra and Analytical Geometry Macroeconomics	Computer Programming II Electricity and Electronics Mathematical Analysis II Computer Aided Design Numerical Analysis
2	Mathematical Analysis III Mechanics I Thermodinamics Statistics Microeconomics	Mechanics II Multivariate Statistics Materials Fluid Mechanics Sensors and Actuators
3	Operational Research I Strength of Materials Heat Transfer Programmable Logic Systems Manufacturing Processes	Accounting Information Systems I Operations Management Industrial Informatics (optional) Design and Manufacturing (optional) Energy Management and Environment (optional)

4	Financial Management Logistics Management Total Quality Management Operational Research II General Management	Project Appraisal Maintenance Management Business Analytics Information Systems II Marketing
5	Management Control Systems Operations Management Project Corporate Strategy Company and Business Law (optional) Technological Entrepreneurship Laboratory (optional) Business Processes Modeling (optional)	Dissertation

Table 1: MIEGI study plan

On March 11, 2020, WHO declared the Covid-19 a worldwide pandemic, the first recorded case in Portugal dated March 2nd (WHO, 2020). This was during the second semester of the academic year 2019-2020. During this semester, an entirely remote ERT system was adopted. In the subsequent semester (1st semester of 2020-2021), classes started to be taught in a mixed regime, in which theoretical classes were taught at a distance (online) and practical classes were taught face-to-face in the classroom. Most laboratory classes had the participation of a part of the students in the classroom and another part at the distance, alternating every week. After Christmas and New Year's Eve, the pandemic situation in Portugal worsened and the second semester of the 2020-2021 school year started completely at a distance, transitioning to the same mixed regime as in the previous semester on April 19th (this corresponds to approximately the middle of the semester). In the remaining period under analysis, between 2016 and 2019, a completely face-to-face teaching regime was adopted.

2.2. Participants

The sample comprises higher education students who attended the Integrated Master in Industrial Engineering and Management from the Faculty of Engineering of the University of Porto. About 500 students attend the program each year. These are mostly Caucasian students aged between 18 and 23 years old.

2.3. Instrument

The instrument used corresponds to the pedagogical questionnaires that are given to students at the University of Porto at the end of each semester since 2016-17 (Porto, 2017.) (this kind of surveys is applied at the University of Porto since 2007-08, with a different format until 2016-17). The application of these surveys allows for a better understanding of the university's pedagogical excellence and allows students to actively participate in improving the quality of the educational process that directly affects them. The choice of this instrument for analysis is due to its widely tested validity (Lemos et al., 2014) and the fact that it has been applied to students at the University of Porto since 2016-17, allowing a comparison of the situation before and during Covid-19.

At the end of each semester of the academic year, students are invited to answer, online, the pedagogical questionnaires for each course and instructors involved, and on their (student) involvement in the course. The survey format includes statements that students should rate on a scale of 1 to 7, where “1” means a very low level and “7” a very high level of the assessed characteristic (see **Table 8** in the Appendix). These statements are grouped into dimensions according to the parameter to be evaluated. Thus, regarding courses’ quality, instructors’ performance and students’ involvement, 4, 4, and 1 dimensions are evaluated, respectively. Regarding the courses, the following dimensions are evaluated:

a) **Evaluation**: reflects the students' perceptions regarding the assessment procedures used in the course (2 items);
b) **Clarity**: appreciation and Clarity focus on the Structure, contents and functioning of the course (3 items);
c) **Effects:** refers to the Effects of the course on the student, that is, the contributions of the course to the promotion of research/intervention knowledge and skills (5 items);
d) **Difficulty**: refers to the level of previous preparation, work and time required to obtain approval in the course (2 items). It is noteworthy that although the formulation of this question follows the direction of the others, students often tend to distort the application of the Likert scale and assign higher values (e.g. 7) to higher difficulty levels rather than adequate difficulty levels. Therefore, all analyzes performed for this dimension must be interpreted with some caution.

As for the instructors, the following dimensions are evaluated:

a) **Support**: Support for autonomy highlights the opportunities for self-determination, including the possibility to choose activities related to the interests of students, the recognition of their opinions and participation, as well as the reduction of control, surveillance and pressure mechanisms (4 items);
b) **Consistency**: Consistency and help refers to the reliability of the teacher and the provision of teaching/learning Support materials (3 items);
c) **Structure**: appeals to the learning Structure and the amount of information available about the means that lead to the achievement of desired results, including Clarity of expectations, Consistency and adequacy of teaching strategies at the student level (3 items);
d) **Relationship:** refers to the quality of the interpersonal Relationship , including the time to communicate, the expression of positive affection in interactions and the sensitivity to individuality (2 items).

Students' involvement is evaluated using the following dimension:

Involvement: refers to their motivation, involvement and participation, reflecting an active intervention of the student (5 itens).

2.4. Data Analysis

This analysis considers two distinct moments: the pre-Covid-19 phase (*PCovid*) that covers all academic years from 2016-17 to the first semester of the 2019-20 academic year (7 semesters), and the during Covid-19 phase (*DCovid*) that covers the second semester of the academic year of 2019-20 and the academic year of 2020-21 (3 semesters).

Table 2 summarizes the data collected through the questionnaires. For example, for the 1st semester of the academic year 2016-17, 590 responses were obtained for the 27 courses. It should be noted that a student can evaluate all courses he/she is enrolled in a given semester, so the total number of potential answers to questionnaires is higher than the total number of students registered in MIEGI. The same happens for the case of teachers, as each course may have more than one instructor. Each answer to a given course, teacher and student involvement implies the evaluation of the 4+4+1 dimensions, respectively.

Year	**2016-17**		**2017-18**		**2018-19**		**2019-20**		**2020-21**	
Semester	**1^{s}**	**2nd**	**1^{s}**	**2nd**	**1^{s}**	**2nd**	**1^{s}**	**2nd**	**1^{s}**	**2nd**
semester l	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No of students enrolled	459		449		447		456		502	
Response rate	23%		22%		20%		19%		21%	
No of responses about courses and students' involvement	590	400	529	376	479	365	480	329	540	449
No of courses	27	22	27	22	27	22	27	22	27	22
No of responses about instructors	939	680	885	607	835	630	833	580	1019	704
No of instructors	45	41	52	38	55	43	57	42	58	43
	Pre-Covid-19 Phase							During Covid-19 Phase		

Table 2: Number of responses, courses and instructors per year and semester

A first analysis consisted of comparing higher education students' perceptions on the quality of courses, performance of instructors and students' involvement, before and during the pandemic. The following analyzes were performed:

1. Comparison of the pedagogical questionnaires results before and during the pandemic, by calculating the variation of their averages.
    a. Comparison of the average results according to the position of the student in the study plan of the degree.
    b. Comparison of the average results according to the field of science to which they refer.
    c. Comparison of the average results according to the type of classes taught.
2. Evolution of the pedagogical questionnaires results over time, using an approach inspired in the Difference in Differences (DID) method.

All these analyzes were performed using MATLAB®.

3. Results

This section details the results obtained through the analysis of pedagogical questionnaires and is divided into the following sub-sections: perceptions about courses, perceptions about instructors, and students' involvement.

3.1. Perceptions about courses

The first analysis consisted of comparing the evaluation of courses before and during the pandemic, by calculating the variation of the average results between these periods. Students evaluate the courses in four dimensions, namely Difficulty, Evaluation, Clarity and Effects through a scale from 1 to 7. Thus, each observation x_{ijkl} corresponds to the answer of the student i $(i = 1, \dots, m)$, to the dimension j $(j = 1, \dots, 4)$ of the course k $(k = 1, \dots, 49)$ in the semester l $(l = 1, \dots, 10)$. Then, the average of all the answers obtained for each dimension j , considering each course k in PCovid period, is calculated, as shown in Equation (1).

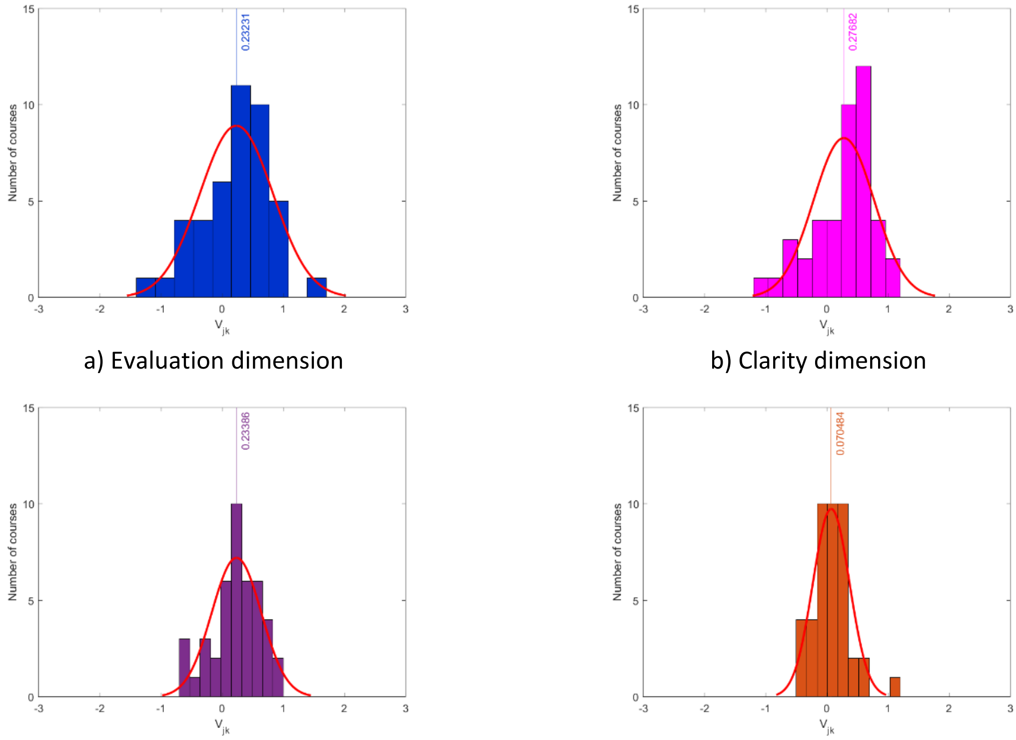
$$PCovid_{jk} = \left(\sum_{l=1}^{7} \sum_i x_{ijkl}\right) \times \frac{1}{7}, j = 1, \dots, 4, k = 1, \dots 49 \tag{1}$$

The $DCovid_{jk}$ is computed similarly as in Equation (1) for semesters $l = 8, 9, 10$.

Then, the variation (V_{jk}) of the mean values defined in Equation (1) was calculated to compare the set of semesters during Covid ($DCovid_{jk}$) and pre-Covid ($PCovid_{jk}$), for each dimension j of each course k, as shown in Equation (2).

$$V_{jk} = DCovid_{jk} - PCovid_{jk} \tag{2}$$

To ensure the representativeness of the perceptions on courses quality, we only included in the analysis the observations on students' answers to questionnaires for courses with at least 10 answers in a given semester. **Figure 1** shows the variation between the PCovid and DCovid phases for all courses.



a) Evaluation dimension

b) Clarity dimension

c) Effects dimension

d) Difficulty dimension

Figure 1: Courses evaluation per dimension

The overall results demonstrate that the average variation between the phases during and before covid-19 is positive, in all dimensions, meaning an improvement in perception of students in relation to the courses in the DCovid phase (see **Figure 1**). All dimensions follow a normal distribution, with the Evaluation dimension having a mean of 0.23 and SD of 0.59, Clarity a mean of 0.27 and SD of 0.49, Effects a mean of 0.23 and SD of 0.40 and Difficulty a mean of 0.07 and SD of 0.29, the latter being the dimension with the smallest variation and the mean closest to 0.

Additionally, a comparison of the results of the evaluation of courses was carried out according to the position of the student in the study plan of the degree (i.e., 1st year, 2nd year, …). With this analysis we intend to understand if there are differences in the evaluation of students that may be attributable to the position of the student in the study plan. To this end, a one-way analysis of variance (ANOVA) was performed. The null hypotheses considers that there are no differences between $PCovid_{jk}$ and $DCovid_{jk}$for the for the dimension j of the courses k that belong to the same school year. We assume that the null hypothesis is rejected for a p-value < .10 (Kim & Kim, 2020; T., 2008).

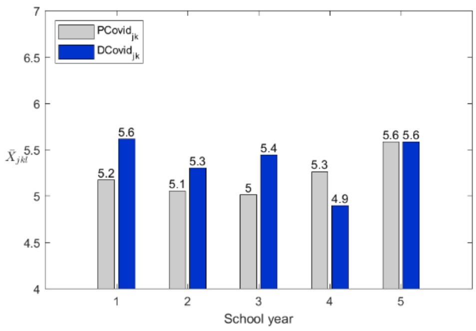
Table 3 summarizes the ANOVA results, with p values below the defined threshold (<.10) being identified in gray. Analysis of the results allows to verify that the null hypothesis is rejected for all dimensions of the first school year. It is also rejected for the dimensions Clarity and Effects of the second year, and Evaluation and Effects of the third year. In the fourth and the fifth year there are no statistically significant differences in students' perceptions of the phases before and during Covid regarding the courses.

	Year in the study plan				
Dimension	**1**	**2**	**3**	**4**	**5**
Clarity	0.0012***	0.0106**	0.1822	0.1066	0.9076
Evaluation	0.0221**	0.1442	0.0720*	0.1562	0.9991
Difficulty	0.0720*	0.8809	0.9730	0.8498	0.4295
Effects	0.0006***	0.0333**	0.0639*	0.2646	0.6334

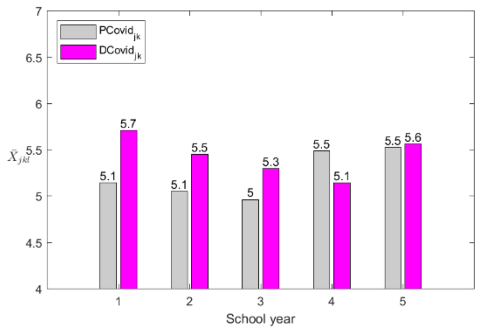
$*** = p < .01$, $** = p < .05$, $* = p < .10$

Table 3: ANOVA p-values for courses

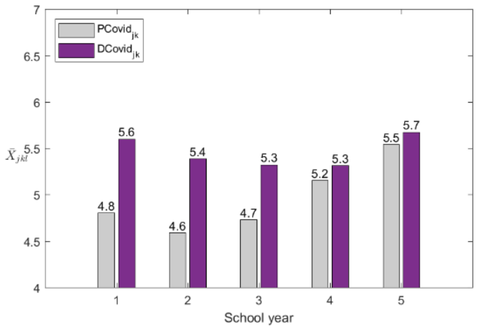
A graphical representation of the evaluation of the courses before and after the Covid-19 by the position of students in the study plan is provided in **Figure 2**. This analysis shows that, as a general rule, students' perceptions are high in the 1st year, decrease in the 2nd and 3rd years and increase again in the last years (4th and 5th). A more detailed analysis by dimension allows verifying that the assessment of 1st, 2nd and 3rd year students is higher in the Covid-19 phase in relation to the Clarity, Evaluation and Effects dimensions. Grade 4 students tend to assess the dimensions of Clarity and Evaluation more positively in the pre-Covid-19 phase, and grade 5 students assess the two dimensions in the two phases in a similar way (see **Figure 2** (a)) and (b). The Effects dimension was evaluated more positively by students of all grades in the DCovid phase (see **Figure 2** (c)). Regarding the Difficulty dimension, there is a decline in the assessment of this dimension by 2nd and 3rd grade students and an increase in 1st, 4th and 5th grade students (see **Figure 2** (d)).



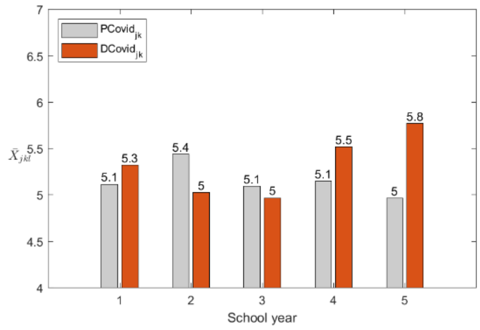
a) Evaluation dimension



b) Clarity dimension



c) Effects dimension

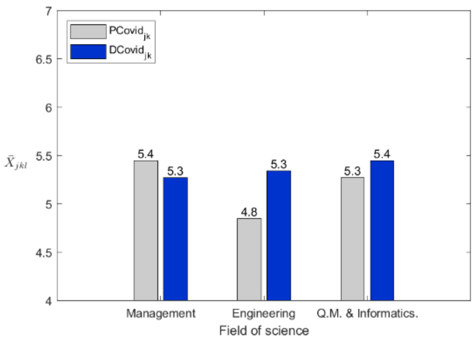


d) Difficulty dimension

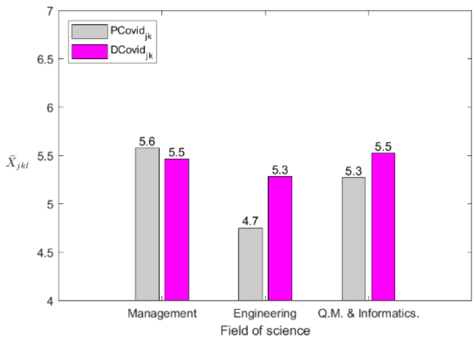
Figure 2: Courses evaluation by students' position in the study plan

Furthermore, the multidisciplinarity of the MIEGI course allowed for an analysis of the students' perception of the courses quality according to the field of science. Therefore, the courses were grouped according to the field of science to which they belong, namely: management, engineering, and quantitative methods & informatics.

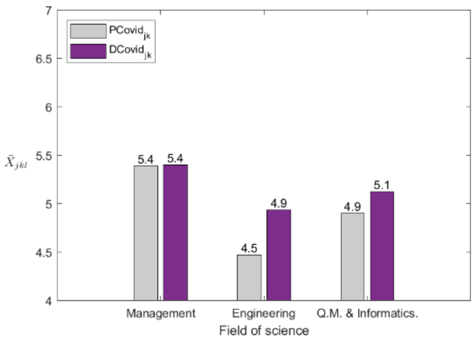
Table 9 in the Appendix details this grouping. Analysis of **Figure 3** allows to verify that the areas of management and quantitative methods & informatics, maintained some stability of results in the pre and during Covid phases in all dimensions, with very slight improvements or declines. The engineering area was the one that verified a significant increase from the PCovid phase to the DCovid phase in almost all dimensions (it was also the area with the lowest pre-covid values and therefore with the greatest scope for improvement). The scientific areas of automation, design and applied mechanics stand out with the greatest growth among the engineering field. As for the Difficulty dimension, the results are very similar in the PCovid and DCovid phases, with a slight increase in the areas of engineering, quantitative methods and informatics in the DCovid phase (see **Figure 3** (d)).



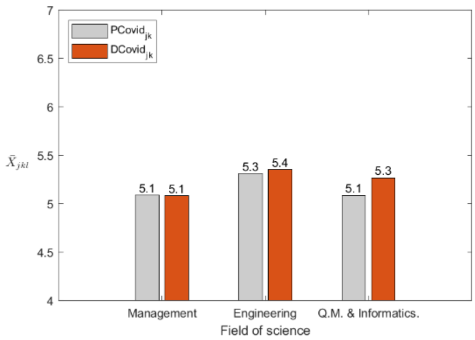
a) Evaluation dimension



b) Clarity dimension



c) Effects dimension



d) Difficulty dimension

Figure 3: Courses evaluation by field of science

Additionally, the results of the questionnaires from the PCovid and DCovid phases were compared according to the type of classes taught. The courses were classified according to three types of classes (see Table 9 in Appendix): mostly practical (with less than 50% of theoretical classes in total contact hours), mostly theoretical (with 50% or more of theoretical classes in total contact hours), and classes with a laboratory component (mainly constituted by the automation scientific area). Thus, the analysis of the results in Figure 4 allows to verify that there was an increase in performance in laboratory and mostly theoretical classes and a decrease in classes with a broader practical component.

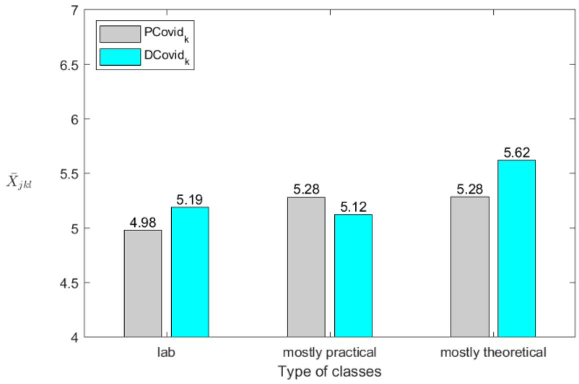
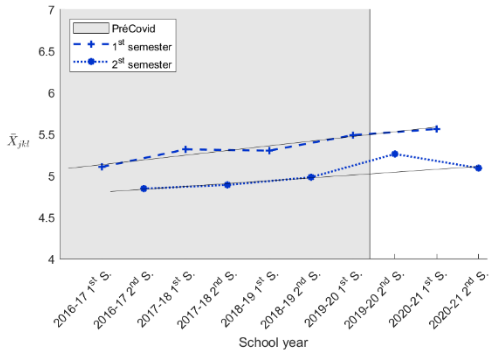


Figure 4: Analysis per type of classes

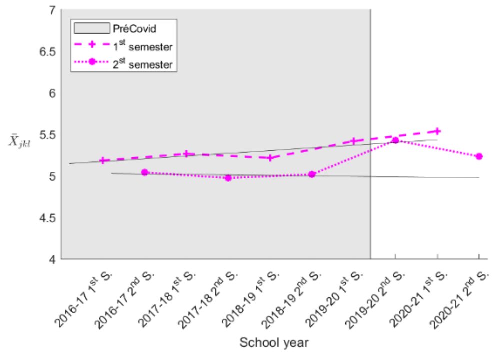
Finally, the evolution of students' perception of the courses quality over time was evaluated. This analysis allows to verify the trends in the assessment of students ($\bar{x}_{jkl}$) over time (l), as well as to individually analyze the three semesters related to the DCovid phase ($l = 8, 9, 10$).

To perform this analysis, an approach inspired in the Difference in Differences (DID) method was used. The DID technique (Angrist & Pischke, 2008) calculates the effect of a particular 'treatment' by comparing the before-and-after differences in outcomes between participants and non-participants. The technique compares a set of treated observations (participants) with a control group of untreated observations to determine the treatment's causal influence (non-participants). To account for contextual changes, the latter group depicts what would have happened if the treated units had not received the treatment, isolating the impact of the treatment in this way. According to (Callaway & Sant'Anna, 2020) in a panel data configuration, the treatment impact can be evaluated using linear regression models.

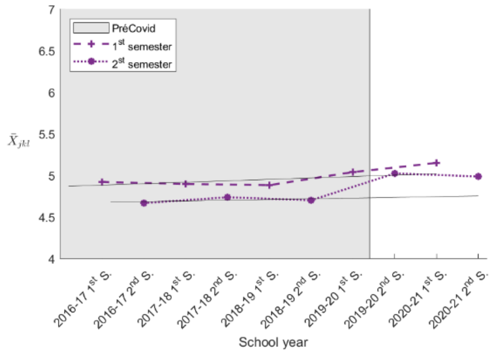
In this case, we consider the observations ($\bar{x}_{jkl}$) to be the treated group and used an Ordinary Least Squares (OLS) regression to estimate a proxy of the control group ($\bar{x}'_{jkl}$), considering the values observed in $l = 1, \ldots, 7$ (pre-Covid phase). Thus, applying a DID-inspired method, we calculate the difference between the treated group $\bar{x}_{jkl}$ and the control group $\bar{x}'_{jkl}$, for each moment of the during Covid period ($l = 8, 9, 10$). **Figure 5** and **Table 4** summarize this analysis.



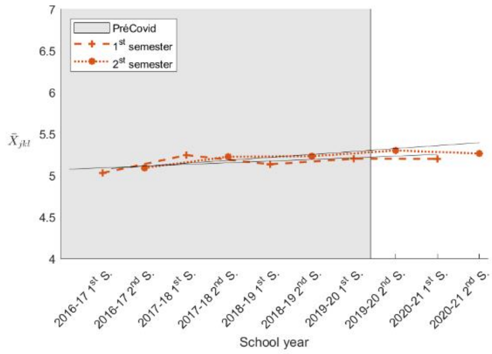
a) Evaluation dimension



b) Clarity dimension



c) Effects dimension



d) Difficulty dimension

Figure 5: Courses evaluation by dimension and semester

Dimension		$l = 8$	$l = 9$	$l = 10$
Evaluation	Observed ($\bar{x}_{jkl}$)	5.260	5.560	5.090
	Estimates ($\bar{x}'_{jkl}$)	5.041	5.584	5.110
	Differences	0.219	-0.024	-0.020
Clarity	Observed ($\bar{x}_{jkl}$)	5.425	5.533	5.231
	Estimates ($\bar{x}'_{jkl}$)	4.985	5.432	4.973
	Differences	0.441	0.102	0.258
Effects	Observed ($\bar{x}_{jkl}$)	5.022	5.149	4.986
	Estimates ($\bar{x}'_{jkl}$)	4.734	5.020	4.751
	Differences	0.288	0.129	0.235
Difficulty	Observed ($\bar{x}_{jkl}$)	5.298	5.197	5.263
	Estimates ($\bar{x}'_{jkl}$)	5.322	5.251	5.393
	Differences	-0.024	-0.054	-0.130

Table 4: Courses differences results

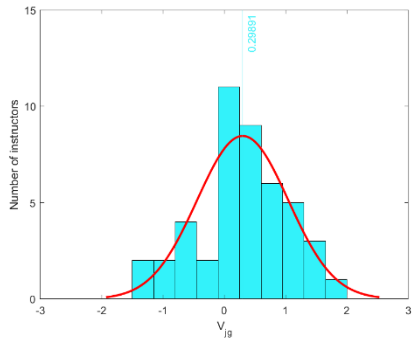
Analysis of **Figure 5** allows to verify that the results of the 1st semester are always superior to those of the 2nd semester, in the case of the Evaluation, Clarity and Effects dimensions. There is also a tendency for growth in student assessments over the years, in the case of the Evaluation and Difficulty dimensions. The analysis of the differences results allows verifying that all dimensions surpass the estimates in the first semester of the Covid phase (see **Table 4**), with the observed values being considerably above the linear regression line (see **Figure 5**). This trend is reversed in the following two semesters, for the Evaluation and Difficulty dimensions, with values lower than those estimated, and with growth in the other two dimensions also being more tenuous. The Difficulty dimension presents higher values in the 2nd semester from the year 2017-18 onwards, since students tend to associate higher vales to a higher degree of Difficulty and therefore works almost in the opposite direction of the other dimensions (see **Figure 2** (d)).

3.2. Perceptions about instructors

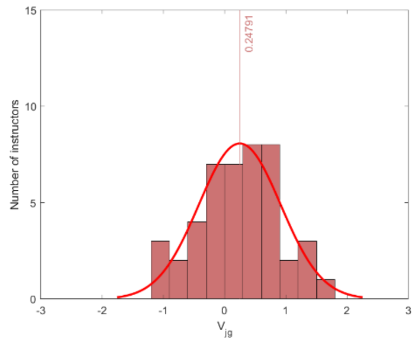
Similar to the analysis performed for the courses, the first analysis consisted of comparing the evaluation of instructors' performance before and during the pandemic, by calculating the variation of their averages. Students evaluate the instructors according to four dimensions: Support, Consistency, Structure, and Relationship. Thus, each observation x_{ijgl} corresponds to the answer of the student i $(i = 1, \dots, m)$, to the dimension j $(j = 5, \dots, 8)$ of the instructor g $(g = 1, \dots, 126)$, and, semester l $(l = 1, \dots, 10)$.

The calculation of the average $PCovid_{jg}$ of all the answers obtained for each instructor is similar to Equation (1), but in this case the variable k (course) is replaced by the variable g, which concerns to the instructors. Likewise, the variation (V_{jg}) of the mean values defined in Equation (1) was calculated according to Equation (2), for each dimension j of each instructor g.

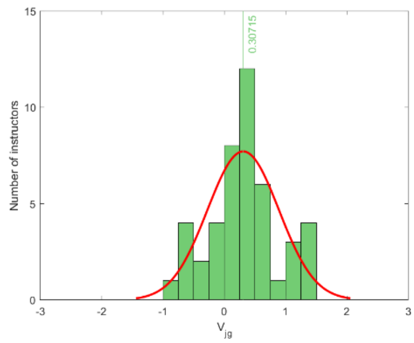
Figure 6 shows the variation between the PCovid and DCovid phases for all faculty with more than 10 answers (to ensure the representativeness).



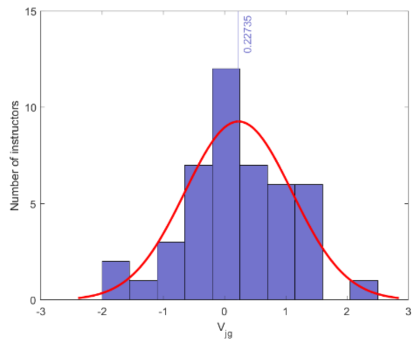
a) Support dimension



b) Consistency dimension



c) Structure dimension



d) Relationship dimension

Figure 6: Instructors evaluation per dimension

The overall results reveal a positive variation between the PCovid and DCovid phases for all dimensions, meaning a positive perception of students in relation to instructors (see **Figure 6**). All dimensions follow a normal distribution, with the Support dimension having a mean of 0.29 and SD of 0.74,

Consistency a mean of 0.24 and SD of 0.66, Structure a mean of 0.30 and SD of 0.58 and Relationship a mean of 0.22 and SD of 0.87.

Additionally, a comparison of the results of the evaluation of instructors was carried out according to the position of the student in the study plan of the degree. To this end, a one-way analysis of variance (ANOVA) was performed. The null hypotheses considers that there are no differences between $PCovid_{jg}$ and $DCovid_{jg}$ for the dimension j of the instructors g that teach in the same school year. We assume that the null hypothesis is rejected for a p-value < .10 (Kim & Kim, 2020; T., 2008).

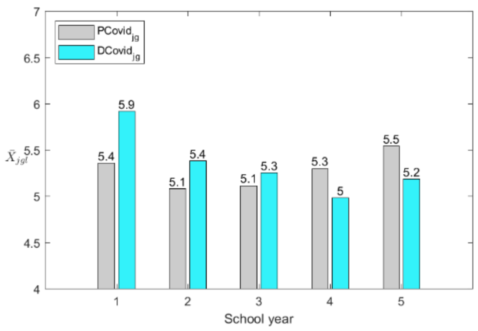
Analysis of the ANOVA results (see **Table 5**) shows that the null hypothesis is rejected for all dimensions of the first school year. It is also rejected for the dimensions Support and Consistency of the second year. In the other dimensions and in the remaining years there are no significant differences in students' perceptions of the phases before and during Covid regarding the instructors.

	Year in the study plan				
Dimension	**1**	**2**	**3**	**4**	**5**
Support	0.0012***	0.0362**	0.6050	0.1987	0.9389
Consistency	0.0020***	0.0763*	0.4394	0.7369	0.3298
Structure	0.0004***	0.1479	0.4348	0.3886	0.8710
Relationship	0.0181**	0.4025	0.6549	0.3159	0.5882

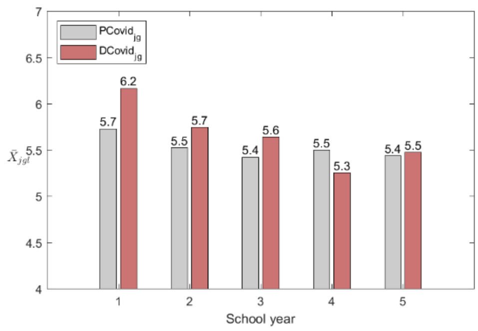
$*** = p < .01$, $** = p < .05$, $* = p < .10$

Table 5: ANOVA p-values for instructors

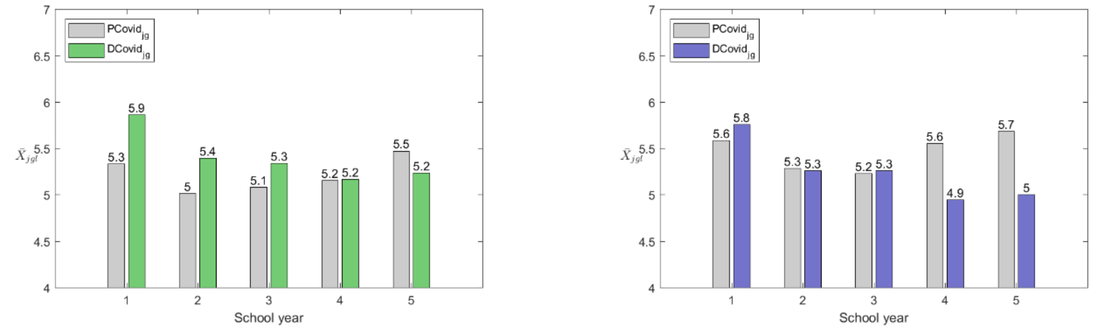
A graphical representation of the evaluation of the instructors before and after the Covid-19 by the position of students in the study plan is provided in **Figure 7**. Similar to the courses, the same “valley effect” is verified in the Evaluation of instructors, particularly in the PCovid phase: better evaluations by students of the 1st, 4th and 5th years and worse by the students of the 2nd and 3rd years. Interestingly, this “valley effect” is lost in the DCovid phase, with the assessment of instructors by 1st grade students being the highest, decreasing consecutively over the years.



a) Support dimension



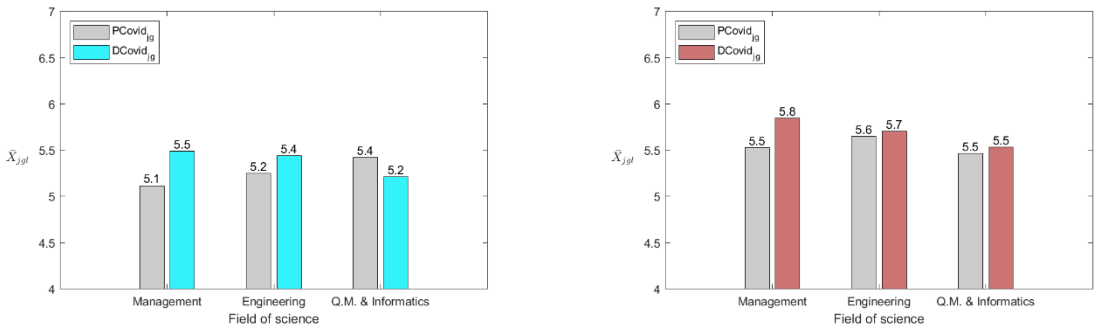
b) Consistency dimension



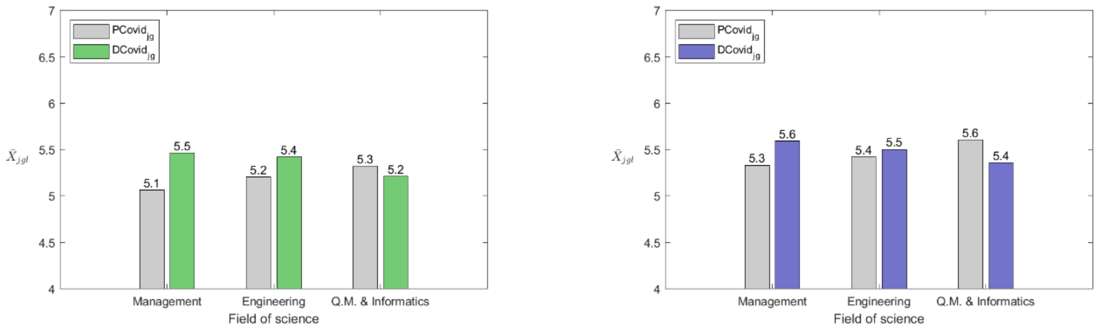
c) Structure dimension d) Relationship dimension

Figure 7: Instructors evaluation by students' position in the study plan

Similar to the analysis carried out for the courses, a PCovid and DCovid analysis was also carried out for the instructors regarding the field of science they teach (see **Figure 8**). Thus, it is possible to verify that instructors from the science fields of management and engineering verified an increase in the evaluations of students from the pre-covid phase to during the covid, in all dimensions, with the increases in the area of management being a little more significant. The field of quantitative methods & informatics verified a slight decrease in all dimensions, except for Consistency.



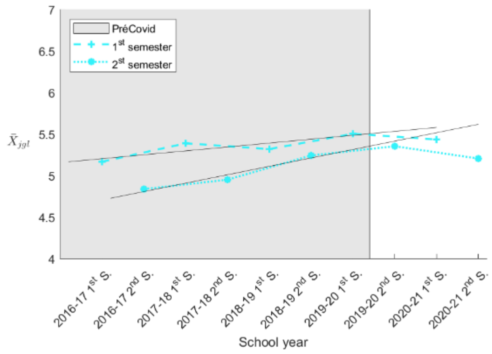
a) Support dimension b) Consistency dimension



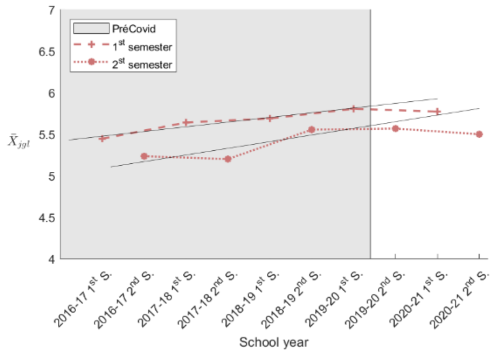
c) Structure dimension d) Relationship dimension

Figure 8: Instructors evaluation by field of science

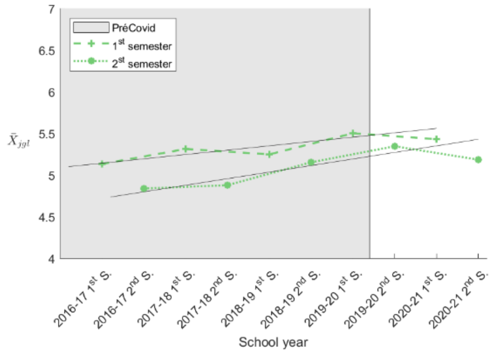
Finally, an analysis of the results of the surveys per semester (l) for instructors was also carried out and the DID-inspired method was used. **Figure 9** and **Table 6** summarize this analysis.



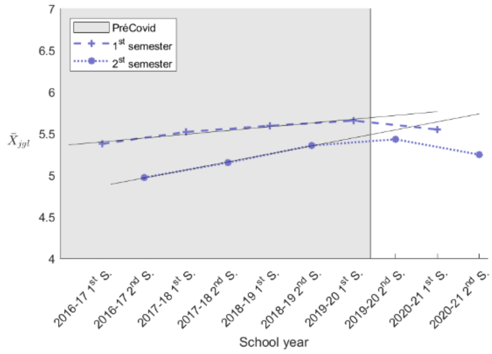
a) Support dimension



b) Consistency dimension



c) Structure dimension



d) Relationship dimension

Figure 9: Instructors evaluation by dimension and semester

Dimension		$l = 8$	$l = 9$	$l = 10$
Support	Observed ($\bar{x}_{jgl}$)	5.353	5.435	5.204
	Estimates ($\bar{x}'_{jgl}$)	5.416	5.580	5.618
	Differences	-0.062	-0.145	-0.413
Consistency	Observed ($\bar{x}_{jgl}$)	5.566	5.771	5.498
	Estimates ($\bar{x}'_{jgl}$)	5.649	5.927	5.809
	Differences	-0.082	-0.156	-0.311
Structure	Observed ($\bar{x}_{jgl}$)	5.346	5.431	5.184
	Estimates ($\bar{x}'_{jgl}$)	5.272	5.561	5.430
	Differences	0.074	-0.129	-0.245
Relationship	Observed ($\bar{x}_{jgl}$)	5.429	5.547	5.245
	Estimates ($\bar{x}'_{jgl}$)	5.543	5.762	5.736
	Differences	-0.114	-0.215	-0.490

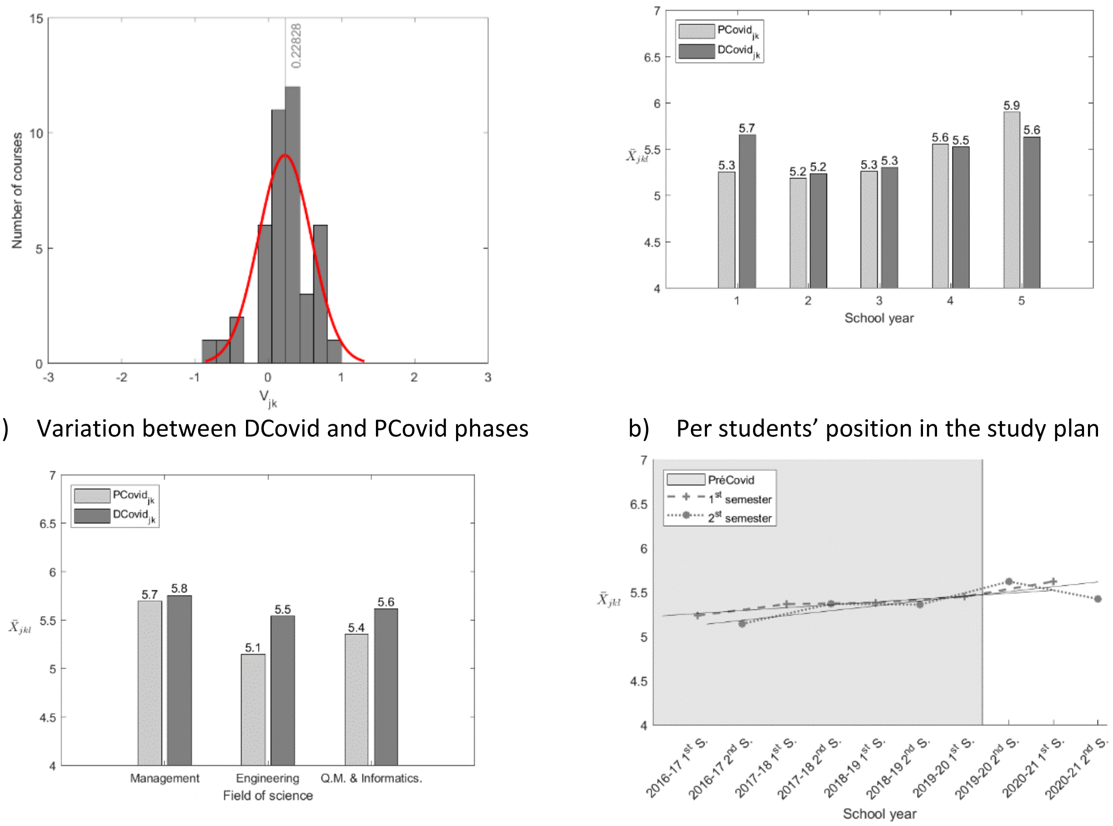
Table 6: Instructors differences results

Overall there are three aspects to highlight from the analysis of **Figure 9**: first, the results of the pedagogical surveys are higher in the first semester than in the second, with a tendency towards approximation in recent years. Second, there has been a growing trend over the years. These surveys, in particular, have been administered at the University of Porto since 2016, and it is natural that courses and instructors adapt in order to improve their teaching and obtain better results in recent years. Third, there is a peak in the 1st semester of the beginning of the pandemic (2nd semester of 2019-20) and a decrease in the results in the two subsequent semesters (1st and 2nd semesters of 2020-21), contrary to the growth trend of the last years.

Analysis of the differences results shows that the values of all dimensions, except Structure, are slightly below the linear regression line in the first semester of the Covid phase (see **Table 5**). The distance between observed values and estimated values tends to increase in the following semesters, with those observed being lower than those estimated in all dimensions.

3.3. Perceptions about students' involvement

When filling out the pedagogical surveys, students are also invited to assess their involvement with the course. An analysis of this dimension was then carried out, similar to the analyzes presented above, and is summarized in **Figure 10** and **Table 7**. An analysis of (**Figure 10** (a)) allows to verify that the variation between the DCovid and PCovid phases is positive, following a normal distribution around the mean of 0.22 and SD of 0.36.



a) Variation between DCovid and PCovid phases

b) Per students' position in the study plan

c) Per field of study

d) Per semester

Figure 10: Student involvement

Dimension		$l = 8$	$l = 9$	$l = 10$
Involvement	Observed ($\bar{x}_{jkl}$)	5.620	5.620	5.423
	Estimates ($\bar{x}'_{jkl}$)	5.507	5.521	5.616
	Differences	0.113	0.099	-0.193

Table 7: Students differences results

An analysis of the involvement dimension according to the students' position in the study plan demonstrates that the "valley effect" is maintained: higher values in the 1st, 4th and 5th years, and lower values in the 2nd and 3rd years. An ANOVA was also calculated for this dimension, being the null hypothesis rejected for the 1st, 2nd and 3rd school years, since the p-values are below the defined threshold (.10). Additionally, an analysis of the dimension of involvement by field of study shows that the involvement of students with the courses increased in all fields during the Covid phase.

Finally, it is possible to verify a growth trend over the years, reaching the peak in the 1st semester of the DCovid phase (2nd semester 2019-20), and maintaining itself in the following semester (1st semester 2020-21) (see **Figure 10** (b)). In the last semester of the DCovid phase (2nd semester 2020-21) there is a significant decrease. These conclusions are corroborated by the values of the differences results presented in **Table 7**.

4. Discussion

The results of this study allowed for a comprehensive analysis of the evolution of students' perception about courses and instructors in the last 5 years (2016-2021), through the analysis of the results of the pedagogical questionnaires. It also allowed to understand the impact of the Covid-19 pandemic on students' perceptions, by comparing the period before and after Covid-19. In general, it is possible to verify that the results of the pedagogical questionnaires have been growing positively over the years, indicating an evolution and improvement in pedagogical practices in MIEGI at FEUP. It is also noted that the results are higher in the first semester than in the second, with a tendency towards approximation in recent years.

Regarding the analysis of the DCovid phase, it is possible to identify two distinct moments. The first moment corresponds to the first semester of Covid-19 (2nd semester 2019-20), when Covid-19 was declared a worldwide pandemic, closing schools and universities around the world and forcing distance classes. During this period, the results of the pedagogical surveys, both for courses and for instructors, reached the best results ever compared to the same semesters in previous years. We believe that this increase is not only due to the exceptional performance of the courses and instructors per se, but to a phenomenon related to an increase in cooperation and a sense of unity in the face of an adverse situation (Wolloch, 2016). In fact, painful experiences can promote cooperation within social groups (Bastian et al., 2014, 2018), translating in this case into feelings of admiration and empathy of students by instructors and by the educational institution in being able to adapt in such a short time.

The second moment corresponds to the second and third semester of the Covid-19 phase (1st and 2nd semesters 2020-21), in which the benevolence and understanding of the students gave rise to less comprehension and higher expectations. In the 1st semester of 2020-21, the first evidence of student discontent was reflected in the assessment of instructors, which became even more pronounced in the 2nd semester of 2020-21, both in relation to courses and instructors, as the DID-inspired results demonstrate. Additionally, the measures and extra work taken to provide a "secure" environment for all in the campus, might have contributed in a negative manner for the instructor's evaluation.

Thus, at a first moment affective and social factors of cohesion, unity and understanding overlapped the situation experienced, translating into a comprehensive and friendly assessment by the students. Over time, the accumulated fatigue, the lack of patience and comprehension, the permanence of a situation that was expected to be transitory, resulted in a more demanding assessment by the students.

In relation to the courses, it is possible to verify an improvement in all dimensions in the first two semesters of the DCovid phase (2nd semester 2019-20 and 1st semester 2020-21), compared to homologous semesters of previous years. Students considered that the objectives of the courses were relevant, contributing to the deepening of training in the area, that the assessment methods were adequate, and with a similar degree of difficulty of previous years. In general, it can be said that the emergency situation experienced did not negatively impact the students' perception of the courses, quite the contrary.

On the other hand, the last analyzed semester of the DCovid phase (2nd semester 2020-21), registered a sharp reduction, although above the linear regression line, in the evaluation of students in relation to all dimensions of the courses. It should be noted that this semester's classes were started completely remotely and ended in a hybrid format. Thus, the students considered that the structure, contents and functioning of the courses were not properly adapted to this mixed regime. In addition, students used to stay at home and attend classes from a distance (many of them had returned to their homeland) did not understand why they had to go back to university in the last month of school. All these factors, added to fatigue and lack of understanding, led to a deterioration in the students' appreciation of the courses.

Another interesting fact to be analyzed is the perceptions of students according to their position in the study plan. Older students, from the 4th year, with previous experience in face-to-face education and without restrictions, tended to consider the structure, contents, functioning and evaluation procedures of courses in the ERT system worse. Additionally, 4th and 5th grade students considered that the degree of difficulty and the volume of work required are higher in the ERT system. Younger students, who have never or had little university experience in normal situations, gave higher grades to courses in all dimensions, contrary to the trend observed in the years prior to Covid-19 and contributing to a statistically significant difference between the two periods.

Regarding the type of subject taught, there is a tendency for more technical, quantitative and engineering courses to become clearer and more appreciated in the DCovid phase, leveling off with the others such as economics, management and operations. Students also considered that the evaluation methods of those courses also became more adequate, having worsened the case of courses in the area of operations management, for example. This could indicate that some types of courses are easier to adapt and improve for ERT.

From the analysis carried out, it was also clear that courses with a greater component of theoretical classes obtained better student evaluations during Covid. The same happened with the courses that require hands-on experience in laboratories, which were taught at a distance, obtaining better evaluations than in the PCovid period. On the other hand, courses with a greater practical component found a decrease in assessments during Covid, suggesting difficulties in adapting practical classes to the ERT systems.

In relation to the instructors, it is possible to verify an improvement in all dimensions in the first semester of the DCovid phase (2nd semester 2019-20), compared to previous years. These data indicates that, during the first confinement there was a greater effort on the part of instructors to adapt the syllabus to the new reality of ERT, monitor and support students, foster a good relationship , and stimulate their motivation and interest in the course. The fact that they are all experiencing an abnormal and unknown situation brought students and instructors together in some way, giving rise to more affective factors such as empathy and solidarity.

The last two semesters of the DCovid phase (1st and 2nd semesters 2020-21), registered a reduction in the evaluation of students in relation to all instructors' dimensions. The students became more demanding, got to know all the possibilities opened up by the introduction of new technologies in teaching and perhaps expected a greater adaptation and structuring of the syllabus to the new reality, which may not be possible in situations where resources are scarce and where everything works in a state of emergency.

The relationship with students was also severely affected in this ERT model, either by the more expository character of the theoretical classes that were being given remotely, often with instructors talking to students with the cameras turned off, or by the practical classes given in mixed regime, with the tendency to pay more attention to those who were in person in the classroom than to those who were attending the class using online methods. On the other hand, the ability to stimulate motivation and interest in students, the promotion of their critical reflection and the availability to monitor and support students also registered lower evaluations, when compared to the previous year. On the student's part, some might be demotivated by the online classes and expect the in-situ ones to "compensate" for their disconnection.

Again, analysis of the results according to the student's school year shows that older 4^{th} and 5^{th} grade students gave instructors lower grades compared to PCovid years across all dimensions. In this case, the dimension of the interpersonal relationship between the teacher and the student was the one that registered the biggest difference in the assessment (negatively). The pandemic has widened distances between people, reducing communication time, the expression of positive affect and sensitivity to individuality, something that older students were used to in previous years.

Regarding the type of subject taught by the instructors, there is a better adaptation to the ERT model of courses in the fields of management and engineering, and worse in the area of quantitative methods. Regarding the involvement of the student with the courses, there is a maintenance of the trend of the pre-Covid years, except in the last semester of the analysis (2^{nd} semester 2020-21). In fact, the extension of a situation that was expected to be transitory brings a lack of motivation and willingness to actively participate in teaching/learning activities.

5. Conclusion

This study presents a comprehensive analysis of higher education students perceptions about courses, instructors and themselves during the last 5 years (2016-2021), with a special focus on the period during the Covid-19 pandemic. To this end, the pedagogical questionnaires answered by the students from the industrial and management engineering degree at the Faculty of Engineering of the University of Porto at the end of each semester of classes were analyzed.

From the analysis carried out, it is possible to verify that, in general, the questionnaires results have been positive over the years, indicating an evolution and improvement in pedagogical practices. Regarding the period during the Covid-19 pandemic, corresponding to the last three semesters analyzed (2^{nd} semester 2019-20 and 1^{st} and 2^{nd} semester 2020-21), it was possible to identify two distinct moments.

The first moment corresponds to the first semester of Covid-19 (2^{nd} semester 2019-20), when Covid-19 was declared a worldwide pandemic, closing schools and universities around the world and forcing the implementation of ERT models. During this period, the results of the pedagogical surveys, both for courses and for instructors, reached the best results ever compared to the same semesters in previous years. Underlying here are feelings of positivism, admiration and empathy from students for instructors and for the courses they teach, since adverse situations promote unity and cooperation between groups.

The second moment corresponds to the second and third semester of the Covid-19 phase (1^{st} and 2^{nd} semesters 2020-21), in which the benevolence and understanding of the students gave rise to less comprehension and higher expectations. In the 1^{st} semester of 2020-21, the first evidence of student discontent was reflected in the assessment of instructors, which became even more pronounced in the 2^{nd} semester of 2020-21, both in relation to courses and instructors. There was also an increase in the workload of students, who gradually felt less motivated and less involved in teaching/learning activities as the pandemic and ERT spread over time.

The limitations of this study are related to the fact that it analyzes a specific degree, which despite being multidisciplinary is still just one, from a leading university in Portugal. This limitation makes room for future work that consists of analyzing more answers to questionnaires, covering the different courses from FEUP and University of Porto. On the other hand, it will be interesting to analyze the results of subsequent pedagogical surveys, hopefully in a post-Covid-19 period, in order to measure the impact that an ERT model has had on the structuring of future teaching models.

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Appendix

Courses assessment

Difficulty	Workload and time required depending on the objectives and credits of the course; Content Difficulty level.
Evaluation	Valuing student participation in learning activities; Adequacy of the assessment modality to the course objectives.
Clarity	Overall appreciation of the course; Contribution to further training in the area; Relevance of objectives.
Effects	My knowledge and ability to understand the phenomena and themes dealt with; My capacity for critical reflection; My ability to analyze the ethical, social or political implications of the subjects studied;

	My curiosity for new areas of research, intervention or professional practice; My ability to communicate information, ideas and solutions.
Instructors assessment	
Support	Ability to stimulate motivation and interest in students; Promotion of critical reflection by students; Commitment to the quality of teaching/learning; Overall appreciation of the teacher.
Consistency	Availability to monitor and Support students; Compliance with assessment rules agreed with students; Use of information and communication technologies (e-learning, SIGARRA, transfer of documents or presentations in digital format, …).
Structure	Organization and structuring of the contents and activities of the course; Presentation from various perspectives; Use of research contributions or professional practice in teaching.
Relationship	Consideration by students; Good Relationship with students.
Students self-assessment	
Involvement	I used information and communication technologies (e-learning; SIGARRA...) as a study tool; I talked with colleagues about the content/work; I got actively involved in the course; I worked autonomously; I actively participated in teaching/learning activities (classes, assignments or other activities).

Table 8: Items and dimensions of the pedagogical questionnaire

Field of Science	Scientific Area	Course	Year	Sem.	Type of classes
Management	Economics and Management	Project Appraisal	4th	2nd	M. Pract.
		Accounting	3rd	2nd	M. Pract.
		Management Control Systems	5th	1st	M. Pract.
		Company and Business Law	5th	1st	M. Theor.
		Corporate Strategy	5th	1st	M. Pract.
		Financial Management	4th	1st	M. Pract.
		Technological Entrepreneurship Laboratory	5th	1st	M. Pract.
		Macroeconomics	1st	1st	M. Theor.
		Marketing	4th	2nd	M. Pract.
		Microeconomics	2nd	1st	M. Theor.

		General Management	4th	2nd	M. Pract.
		Dissertation	5th	2nd	M. Pract.
	Operations Management	Business Processes Modeling	5th	1st	M. Theor.
		Maintenance Management	4th	2nd	M. Pract.
		Operations Management	4th	2nd	M. Theor.
		Total Quality Management	4th	1st	M. Pract.
		Logistics Management	4th	1st	M. Pract.
		Operations Management Project	5th	1st	M. Pract.
Engineering	Automation	Electricity and Electronics	1st	2nd	Lab.
		Industrial Informatics	3rd	2nd	Lab.
		Sensors and Actuators	2nd	2nd	Lab.
		Programmable Logic Systems	3rd	1st	Lab.
	Design and Manufacturing	Design and Manufacturing	3rd	2nd	M. Theor.
		Computer Aided Design	1st	2nd	M. Theor.
		Industrial Drawing	1st	1st	M. Theor.
		Materials	2nd	2nd	M. Theor.
		Manufacturing Processes	3rd	1st	M. Theor.
	Applied Mechanics	Mechanics I	2nd	1st	M. Pract.
		Mechanics II	2nd	2nd	M. Pract.
		Strength of Materials	3rd	1st	M. Theor.
	Energy	Energy Management and Environment	3rd	2nd	M. Theor.
		Fluid Mechanics	2nd	2nd	M. Theor.
		Thermodinamics	2nd	1st	M. Theor.
		Heat Transfer	3rd	1st	M. Theor.

Quantitative Methods (Q.M.) and Informatics	Informatics	Computer Programming I	1st	1st	M. Pract.
		Computer Programming II	1st	2nd	M. Theor.
		Information Systems I	3rd	2nd	M. Theor.
		Information Systems II	4th	2nd	M. Pract.
	Mathematics	Mathematical Analysis I	1st	1st	M. Theor.
		Mathematical Analysis II	1st	2nd	M. Theor.
		Mathematical Analysis III	2nd	1st	M. Theor.
		Numerical Analysis	1st	2nd	M. Theor.
		Linear Algebra and Analytical Geometry	1st	1st	M. Theor.
	Quantitative Methods	Business Analytics	4th	2nd	M. Pract.
		Statistics	2nd	1st	M. Theor.
		Multivariate Statistics	2nd	2nd	M. Theor.
		Operational Research I	3rd	1st	M. Theor.
		Operational Research II	4th	1st	M. Pract.

Table 9: Grouping of courses by scientific area