

## Impact of COVID-19 on the Integrated Master of Mechanical Engineering of the University of Porto

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### Abstract

This paper focuses on the effect of the current COVID-19 global pandemic on the education system, namely on Mechanical Engineering courses offered at the Faculty of Engineering of the University of Porto. A brief description of the responsive measures adopted is presented regarding the necessary adaptations to distance learning because of law-enforced social distancing and public hygiene measures. Short surveys were answered by both students and faculty members to evaluate their opinion on this topic. Analogous questions on these surveys allowed for the direct comparison of their perspectives. A statistical analysis of students' final marks on all lectured courses was also implemented, which provided insight as to whether distance learning and assessment methods have had significant impact on their performance. This study showed that the pandemic had a significant impact, affecting students and professors.

### Introduction

In the words of UNESCO Director-General Audrey Azoulay, “Never before have we witnessed educational disruption on such a large scale” (UNESCO 2020b). The most recent global crisis, caused by the fast spreading of the new Coronavirus, is having a deep social and economic impact that was unknown to modern civilization. This outbreak significantly affected different sectors of society, such as healthcare systems (Holshue, DeBolt, and Lindquist 2020), agriculture (AVMA 2020), manufacturing (Knieps 2020), and energy (Mohamed 2020). The education system has also been affected: within a few weeks of the beginning of the contagion, over 290 million students were unable to attend school (UNESCO 2020a). Data presented by the United Nations (UNITED NATIONS 2020) indicates that nearly 1.6 billion

learners of 190 different nationalities were affected by this pandemic, accounting for 94 percent of the world's student population affected by the closure of schools and other learning spaces. This figure is even more dramatic in low and lower-middle income countries, ascending to 99 percent. The United Nations also warns about the uncertainty around the education system: the risk of a new tragedy coexists with the possibility of improvement towards a more inclusive and unrestricted education. UNICEF reported that over 1 billion children are at risk of falling behind in their studies due to school closures (UNICEF 2020). Despite the implementation of remote education programs, many children do not have access to the necessary technological means to continue their education, this reality being more dramatic in poorer households. The OECD (Schleicher 2020) reiterates the need for the establishment of a more solid education system, one that will be able to tackle future adversities of this sort.

In the United States, research on learning under conditions similar to the ones students are subject to during the pandemic, anticipates that the challenges of distance learning will evidence social and economic disparities (García and Weiss 2020). These inequalities are not only reflected on education: low-income families are also more likely to experience more stress due to the possibility of job and/or health care loss, the lack of paid sick leave, among others. All these unfavorable conditions are yet another obstacle to students' academic success. Other authors (Onyema et al. 2020) observed that the effect of the pandemic on education is not limited to a decrease in the quality of teaching, but extends to education institutions as a whole: delays in research, job losses and increased student debts are also urgent problems. The adoption of more technologically dependent teaching methods in Nigeria, Bangladesh, India, and Saudi Arabia, was hindered by problems in network connectivity, unavailability and/or inaccessibility of means and insufficient digital skills, either by students or professors. The need for education institutions to improve their digital infrastructures to tackle future challenges of this sort is underlined.

The prospect of an education system based on distance-learning far precedes current global situation. In fact, studies (Pozgaj and Knezevic 2007) have shown that availability of technological resources and willingness to participate in this process are already met in certain student populations. However, the Coronavirus pandemic has shown that this is not a universal truth. In fact, digital inequalities are an obstacle to this transition, as the access to technological resources such as a computer or an internet connection is not universal. Moreover, student-teacher interaction is compromised in remote classes as students are less engaged (Oyedotun 2020). The lack of a suitable space for attending online classes is also an issue. As students are forced to work from home, the variety of possible distractions makes concentrating challenging (Sutton 2020). At last, cybersecurity problems emerge as a result of the intensive use of online resources (Nam 2019). In fact, many methodologies used in universities have been designed with face-to-face education in mind and are not necessarily suitable for distance learning. As the global education system is not far along the path of permanently transitioning to distance learning, techniques for this form of teaching are still not a common practice. Despite a variety of possible drawbacks, this new form of teaching carries its own advantages. Evidently, the flexibility of distance learning allows for students to organize their individual schedules more efficiently. This is promoted by the possibility of recorded lectures and meetings. Additionally, students and teachers continue to be engaged outside the typical classroom situation. Also, the use of technological resources is boosted (Oyedotun 2020).

Despite being clear that many universities around the world have been, over the past years, implementing a new distance-learning methodology, many other institutions remain faithful to the traditional education system, offering most courses and programs on a face-to-face basis. These institutions have been forced to adapt to the impossibility of classroom lessons as imposed by the widespread quarantine regime, resulting in a race to transform an education system established for many years. In Portugal, lockdown was imposed in the middle of the curricular year, resulting in the need for a quick transition into distance learning. However, there were many obstacles to this process. Firstly, the novelty of the online platforms suitable for distance learning was a problem only aggravated by the extensive variety and availability of these products. A learning period was expectable for faculty members to be familiarized with these tools, as the need for this type of skills had not been felt before. An additional problem to distance learning is the fact that, as many institutions remain closed, students with economic difficulties may not have access to a computer and/or a stable internet connection, exposing socio-economic differences and extending their negative impact to the area of education. However, the most significant problem to be overcome is the quality of teaching. In fact, many methodologies used in universities have been designed with face-to-face education in mind and are not necessarily suitable for distance learning. The purpose of this study is, therefore, to evaluate students' perspectives and the impact of distance learning on their performance.

## **1. Materials and Methods**

### ***1.1. Structure of the degree***

The Master's degree in Mechanical Engineering at the Faculty of Engineering of the University of Porto is what is known as an integrated Master, meaning that the first 3 years, corresponding to a typical Bachelor's degree, are combined with the final 2 years, corresponding to a typical Master's degree. Throughout the 5-year degree, courses are offered in a wide range of thematic areas, namely: Automation, Personal and Interpersonal Skills, Drawing, Design and Manufacture, Heat Transfer and Fluid, Physics, Management, Computer Science, Mathematics, Materials, Applied Mechanics, and Production. This panoply of courses allows students to gain extensive knowledge on different industries and engineering applications, presenting them with employment prospects in very diverse markets. Students are also offered the possibility to choose a specialization for the last 3 semesters of the degree, focusing on more specific areas of knowledge within the vast universe of Mechanical Engineering. The current structure of the degree offers 5 possibilities: Automation, Thermal Energy, Production, Conception and Manufacturing, Production Management, and Structural Engineering and Mechanical Design. The extensive group of common courses lectured during the first 5 semester of the program provides students with the necessary skill set to tackle the obstacles in any of these specializations.

Typical course structure distinguishes between theoretical and theoretical-practical classes. The first is usually dedicated to the explanation of the theoretical content of the course, even though it may include the solution of simple exercises as a practical application of this content. The theoretical-practical classes are a necessary complement to the theoretical classes as their goal is to assist students in the solution of more complex exercises. For this purpose, theoretical-practical classes are typically lectured for a smaller number of students, allowing the professor to aid students by providing further explanation of certain topics and answering their questions. Courses with a strong technological component often replace theoretical-practical classes with fully practical classes. These are conducted in dedicated laboratories and

aim to familiarize students with mechanical and electronic components common in Mechanical Engineering applications. Field trips, though not as common, may also be included in certain courses' structure, promoting students' contact with real-life situations and engineering applications.

Depending on the course, evaluation methods may differ slightly. Great emphasis is given to exams, during which students are asked to solve exercises directly related to the contents lectured in that course. This component determines students' ability to solve problems through scientifically accurate methods, as well as promotes their ability to develop a structured line of reasoning. Many courses include a theoretical component as a complement to this evaluation element, aiming to assess whether students fully understand the physical principles behind real-world applications of engineering. This theoretical evaluation may be included during the exam or have a dedicated evaluation moment. Another common evaluation method is individual or group projects. Given a certain theme, students are asked to develop research work and present it on the form of a poster, report and/or oral presentation. For a successful project, aspects such as accuracy and organization of information, presentation and critical analysis must be adequately tackled. To a lesser extent, and almost exclusive to courses with a strong technological component, students may undergo practical evaluations. This evaluation method typically consists of a practical exam during which students may be asked to program a mechanical or electronic component to perform a specified task.

### **1.2. Restrictions and alterations**

As the pandemic began to grow in Portugal, many restrictions were imposed on the normal functioning of society. The closure of all universities in the beginning of march came because of the quarantine regime that lasted for most of the second semester. Consequently, teaching methods and class plans established at the beginning of the semester suddenly became unviable. All forms of presential teaching – theoretical, theoretical-practical, and practical classes – were suspended. In most cases, theoretical classes were delivered by videoconference or pre-recorded and made available for students. Theoretical-practical classes were either lectured through an online platform, as many theoretical classes, or conducted through webchats where professors would propose exercises to students and discuss methods for their resolution. Facing the impossibility of presential classes, practical classes were conducted via recording of the experimental activity and supported by data to be used in reports. All pending field trips were cancelled.

Not only was the typical class structure altered, but also the evaluation process. In fact, due to the restrictions imposed by the health ministry, it was decided that courses specific to each Master's specialization would have distance evaluation. Common courses would maintain presential exams, but their duration would be restricted to a maximum of 90 minutes. This measure meant that profound alterations to typical exam structures were necessary in many courses, posing an additional obstacle for both students and professors. In fact, most final exams in previous years far exceeded a duration of 90 minutes.

### **1.3. Methodology**

The research conducted for this study is based on both a survey and a statistical analysis. The survey consisted of two separate questionnaires, one being directed to students and the other to professors. The questionnaires were constructed in such a way that they allowed for a direct comparison of the answers to certain questions, so that similarities and/or differences between the perspectives of students and professors could be easily identified and analyzed.

One of the main goals of these questionnaires was to collect the opinions from both students and teachers regarding the differences between a semester with distance learning and a normal semester. Because no similar questionnaires had been conducted in previous years, it was necessary to establish a reference level with which to compare the distance learning methodologies. The first questionnaire was made available for all 1047 students, obtaining 195 answers (18.6%). The second questionnaire was made available for all 147 professors, obtaining 55 answers (37.4%). The analysis of this data followed a qualitative approach, as the main concern of this part of the research was to assess and compare the perspectives of students and professors regarding the education process during this untypical semester. 5th year students' answers were disregarded as their number (4) is far lower than the number of answers from other years' students, resulting in 191 answers (18.2%). Of these 191 answers, 38 were from 1st year students, 41 were from 2nd year students, 65 were from 3rd year students, and 47 were from 4th year students.

The second part of the research is, as stated above, the statistical analysis of the final marks obtained over the past four years, in all courses lectured during the second semester. This comprehensive set of data allowed for a robust analysis, based on an ANOVA approach, to identify potentially significant variations on the average mark on each course over the considered period. The ANOVA is a statistical method that identifies, with statistical significance, whether the average value of two or more data sets is equal or different (Stöhle and Wold 1989). This approach is based on hypothesis testing - the null hypothesis (H0) states that all groups have the same mean value, whereas the alternative hypothesis (H1) states that there is a difference between at least two of the groups. The test statistic and respective probability value (p-value) are calculated using probability distributions. The p-value is the probability, assuming that H0 is correct, that the test statistic is equal to the calculated value or more extreme than the calculated value, towards H1. The obtained p-value is compared to the significance level ( $\alpha$ ), which defines the maximum admissible probability of rejecting H0 when it is true. A significance level of 5% was used, meaning that there is a 5% risk of identifying a difference between groups when they are, in fact, equal. However useful the ANOVA technique is in identifying differences between groups, it provides no insight into which groups are different. To confirm these differences, confidence intervals were built to compare the average mark in each year, again for each course. The Scheffé test was preferred over the Tukey Test because the number of students in each course is typically different over the years ("Tukey vs. Bonferroni vs. Scheffe: Which Test Should You Use?" 2020). The scope of this analysis was restricted to students who underwent some form of evaluation process. This decision excludes all students who failed to meet criteria for approval and/or were absent from exams or other evaluation components – this last aspect is particularly important as null marks greatly influence the ANOVA analysis by reducing the average mark of that year.

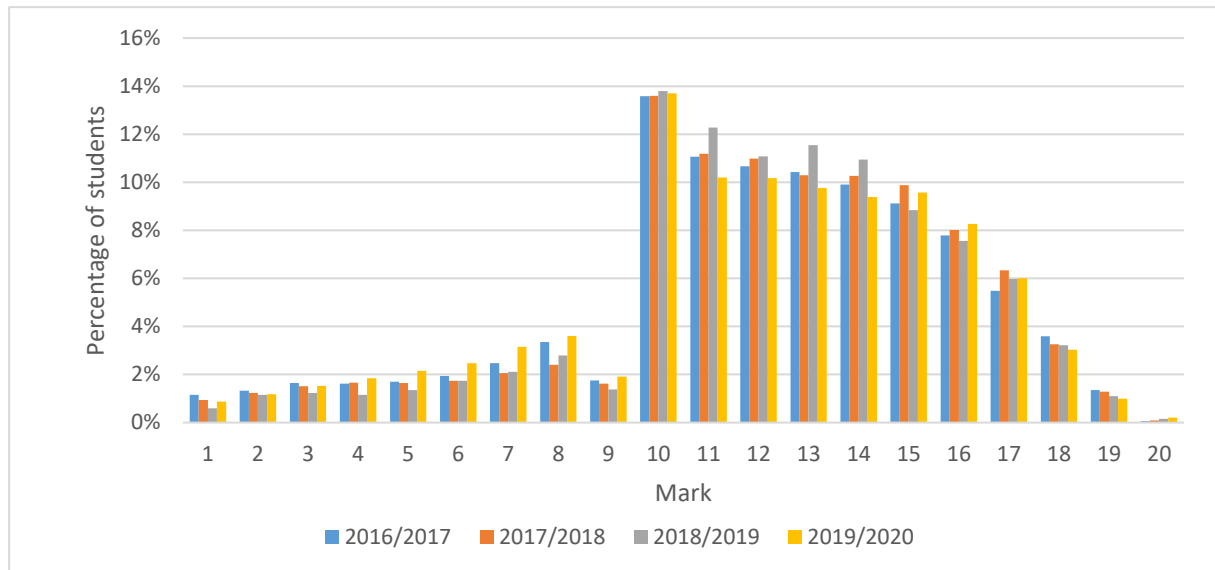
## 2. Discussion

To contextualize the following analysis, the evolution of the average mark for all courses and students of the degree is an adequate statistical indicator, as shown in Table 1. Marks range from 0 to 20, these being the minimum and maximum values, respectively.

**Table 1:** Average mark for all courses and students over the last 4 years

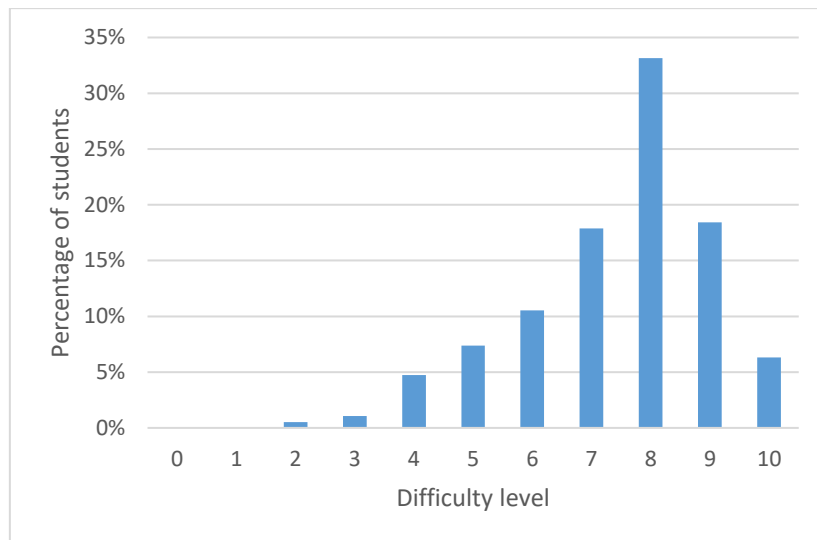
School year	2016/2017	2017/2018	2018/2019	2019/2020
Average mark	11.80	11.93	11.83	11.49

From the evolution of this indicator, it is noted that the average mark from the last school year (2019/2020) is lower than previous years, despite this variation being slim. By applying the ANOVA technique to the global data set, a statistically significant decrease in the 2019/2020 average mark is detected. Although this decrease is small, the calculated p-value is many times smaller than the significance level of 5% used. Figure 1 shows the distribution of marks, for all courses and students, over the last 4 years.



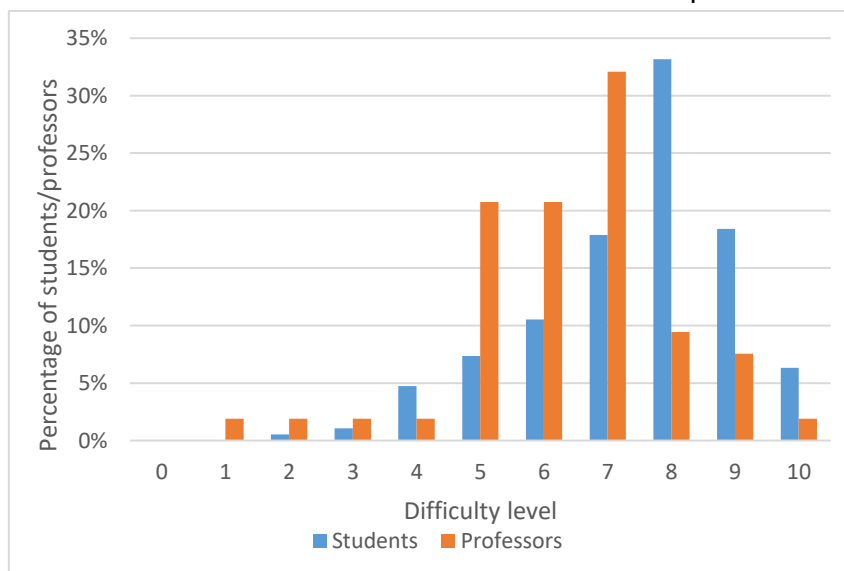
**Figure 1:** Distribution of marks for all courses and students over the last 4 years.

Typical mark distribution is characterized by very few occurrences of low marks (in the range of 1 to 9), a peak at 10 and then a steady descent towards higher marks, for which the occurrence is increasingly scarce. 2019/2020 marks follow this trend, however to a smaller extent: the occurrence of low marks is higher than in previous years, contrarily to the occurrence of higher marks which is less significant. As a result, 2019/2020 average mark is lower than previous years. To further comprehend this conclusion, students' perception of this semester's level of demand is shown in Figure 2.



**Figure 2:** Student's perception of this semester's difficulty level.

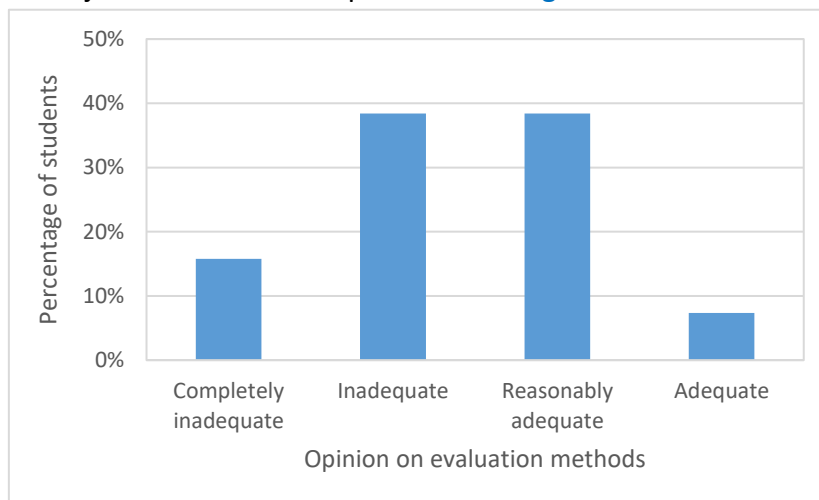
For this question, as well as for similar ones, possible answers ranged from 0 (much lower difficulty level) to 10 (much higher difficulty level). As a reference, 5 was attributed to the difficulty level of a typical semester. Because no prior information regarding students' perception of difficulty level was available, this reference level was established. As shown in [Figure 2](#), students felt that this semester was particularly more demanding than a typical semester, with a resulting average difficulty level of 7.4, evidently higher than the reference level of 5. Compared to previous semesters, students perceived this as more demanding. Accordingly, the global average mark was lower. An interesting conclusion can be drawn from the comparison between students' and professors' perception of this semester's level of difficulty. [Figure 3](#) illustrates the relevant data obtained from the questionnaires.



**Figure 3:** Comparison between students' and professors' perception of this semester's difficulty level.

Observation of [Figure 3](#) leads to the conclusion that professors perceive this semester to be not as demanding as students believe. In fact, professors evaluate this semester as having an average difficulty level of 6.3, substantially lower than the value of 7.4 indicated, on average, by students. This incongruence may evidence a certain mismatch between students and professors. However, being “difficulty” a rather abstract concept, its perception may also be pointed as a cause for this difference. A final remark is presented through the analysis of the

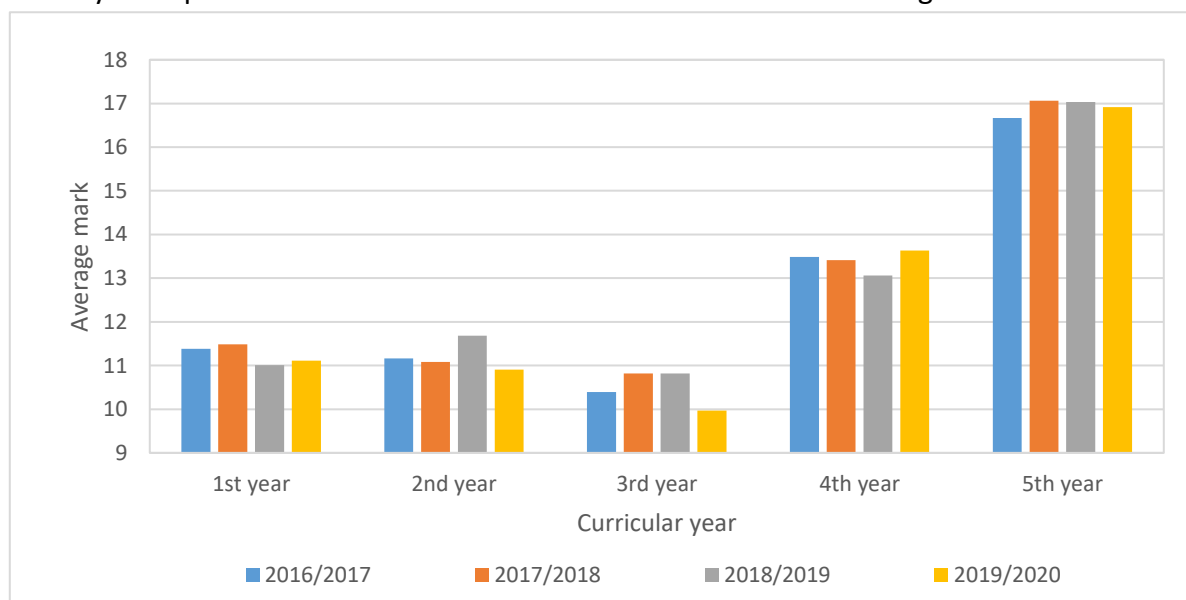
evaluation methods implemented during this semester. As part of the questionnaire, students were asked to express their opinion regarding the adequacy of the evaluation methods to which they were subject. The results are presented in [Figure 4](#).



**Figure 4:** Students' opinion on this semester's evaluation methods.

It is quite clear that, as far as students perceive it, the evaluation methods implemented this semester were far from ideal. In fact, over half the students (54.2%) perceived them as less than reasonably adequate. Considering this result, it is plausible to assume that the overall mark decrease may be linked to the potential inadequacy of the evaluation methods. However, by analyzing the data as a whole, it is impossible to adequately describe more subtle fluctuations and particularities. Therefore, further insight is required.

In a deeper analysis, the previous procedure was now carried out for each year, allowing to detect if students from any particular year saw their average mark significantly affected. For visual inspection of the data, [Figure 5](#) containing the average mark by curricular year and school year is presented – this data is limited to courses lectured during the 2nd semester.



**Figure 5:** Students' average mark by curricular year and school year.

Firstly, [Figure 5](#) shows how students' average mark typically evolves during the 5 years of the degree: during the first 2 years it remains practically unaltered, suffering a slight reduction during the 3rd year and then increasing abruptly in the final 2 years of the degree, corresponding to the Master's specialization courses and the dissertation. Moreover, it



evidences how the average mark for each academic year was affected in 2019/2020. Compared to previous years, the average mark for 3rd year courses is the lowest in 2019/2020. Accordingly, the ANOVA showed a significant reduction of the average mark for 3rd year courses in 2019/2020. On the contrary, the average mark for 4th year courses is the highest in 2019/2020. Accordingly, the ANOVA showed a significant increase of the average mark for 4th year courses in 2019/2020. As for 1st, 2nd, and 5th year courses, the 2019/2020 average mark was within the range of previous years. As a result, the ANOVA could not distinguish any significant variation from expectable variability of the data. Again, these results were compared to students' perception of how demanding this semester was. The perception of the difficulty level of the semester was separated by the year in which students are enrolled, resulting in Figure 6.

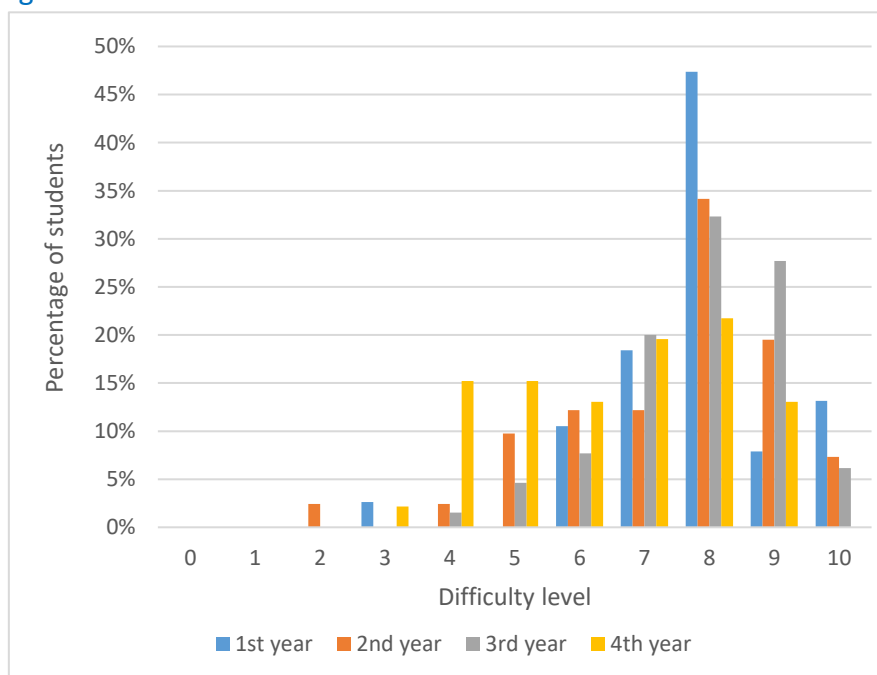
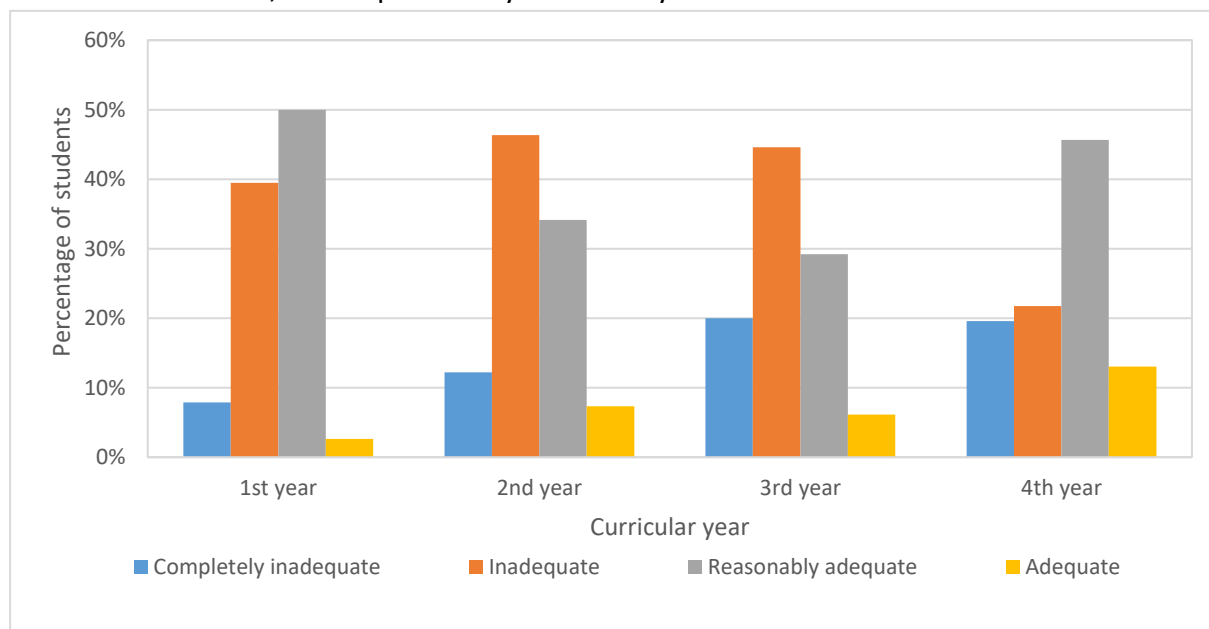


Figure 6: Student's perception of this semester's difficulty level by curricular year.

From Figure 6 it is reasonable to draw the same conclusions as from the previous analysis. When comparing the lines referring to both 3rd year and 4th year, 3rd year students clearly felt more difficulties than 4th year students. In fact, a significant percentage of 4th year students regarded this semester as less demanding than a typical semester – corresponding to a difficulty level lower than 5. This led to 3rd year students evaluating this semester with an average value of 7.8, far higher than the 6.5 average calculated from 4th year students' answers to the questionnaire. Surprisingly, 1st year students also felt great difficulties this semester, tying with 3rd year students also with a 7.8 average value. This may happen since the 1st year in higher education is typically an adaptation period – this contributes to a greater uncertainty among students and may justify this result. Moreover, 1st year students only had 1 semester's experience in higher education to use as a reference level. As far as the 2nd year is concerned, it falls within the average and is not subject to any relevant conclusion. This first analysis is supported by statistical evidence. In fact, even though the ANOVA technique detects significant decrease (considering a significance level of 5%) in the average mark in the 1st, 2nd, and 3rd years, only the decrease in the 3rd year is considered relevant, as the others only appear as statistically significant when compared to a specific previous year. This odd year may occur for different reasons, such as different course planning, different class structure, different evaluation methods or even different organization of the exam calendar,

resulting in an untypically high or low average mark. An increase in the 4th year's average mark is also detected, though it is not considered relevant for the reason mentioned above. Regarding the 5th year, no statistically significant increase or decrease of the average mark is detected. To finalize this topic, [Figure 7](#) shows again students' opinion on the adequacy of the evaluation methods, now separated by curricular year.



**Figure 7:** Students' opinion on this semester's evaluation methods by curricular year.

In any year, roughly half the students feel that this semester's evaluation methods were less than reasonably adequate. This number is, in accordance with previous results, higher for 3rd year students (64.6%) and lower for 4th year students (41.3%), reflecting the respective variations on the average grade and perception of the difficulty level of the semester verified in these years.

From the statistical analysis applied to all 34 courses typically lectured during the second semester of the curricular year, it was verified that in many cases there was no significant variation relative to previous years. In fact, 14 courses (41.2%) saw their average mark unaltered. From the remaining 20 courses (58.8%), 9 (22.5%) had lower marks. A closer inspection to this data subset revealed that in 2 of these courses this semester's average mark was only significantly lower when compared to one previous year. In these cases, it was possible to identify a year in which the average mark was particularly high. It was considered that these statistically significant decreases were not relevant for this study because they were not necessarily an effect of distance learning. Disregarding these cases, the original group of 9 courses whose average mark was lower this semester is reduced to 7 (20.6%). Considering the courses who had a higher average mark this semester, this procedure was repeated. From the 11 courses (32.4%) initially identified, 2 were removed from the scope of the analysis as the apparent increase was only visible against a specific year with an unremarkably low average mark. This resulted in 9 courses (26.5%) for which this semester's higher average mark was not only statistically significant but also relevant. These percentages are shown in [Table 2](#).

**Table 2:** Identification of courses with significant and relevant variations of the average mark

Non-significant variation	Significant variation			Total
	Increase	Decrease		
14 (41.2%)	<b>Odd year identified</b> 2 (5.9%)	2 (5.9%)	4 (11.8%)	20 (58.8%)
	<b>Relevant variation</b> 9 (26.5%)	7 (20.6%)	16 (47.1%)	

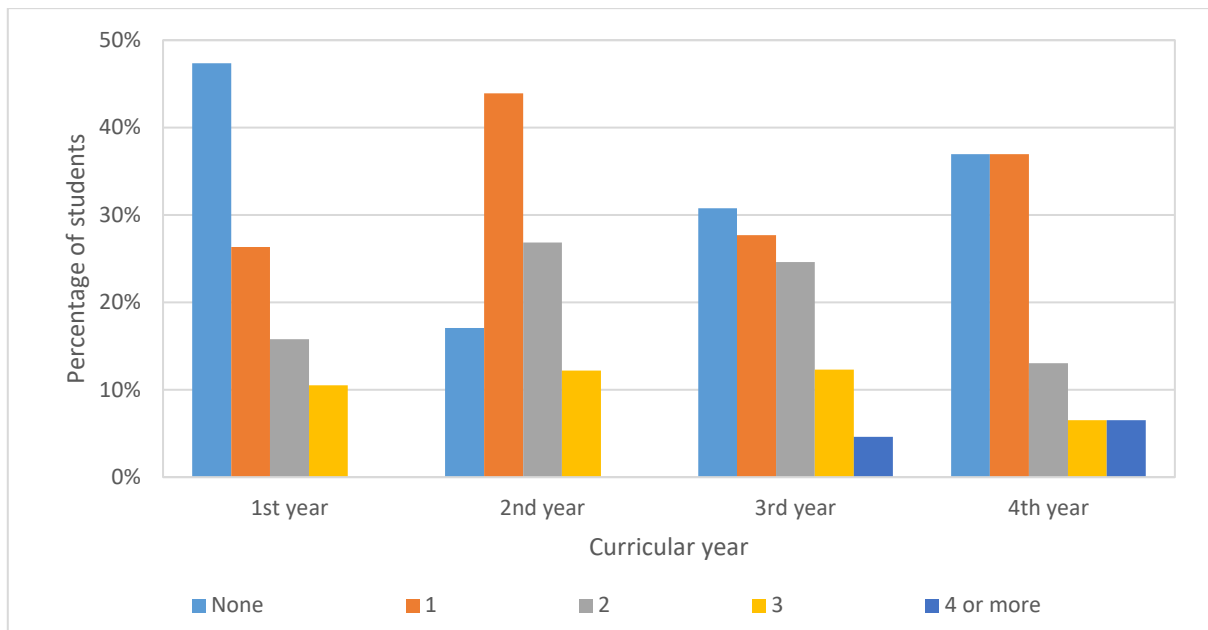
Over half the courses (58.8%) were statistically influenced by this semester’s distance learning methods. As far as relevant variations are concerned, about every other course (47.1%) is identified.

An important aspect to analyze is the incidence of these variations on the different years, theme areas and specializations in which the courses are divided. Of the 9 courses for which the average mark noted a significant and relevant increase, 2 are from the 2nd year, 1 is from the 3rd year, 4 are from the 4th year and 2 are from the 5th year. 1 of the 7 courses with a lower average mark is from the 1st year, 2 are from the 2nd year, 3 are from the 3rd year and 1 is from the 4th year. [Table 3](#) summarizes these results.

**Table 3:** Distribution of courses with significant and relevant variations of the average mark by curricular year

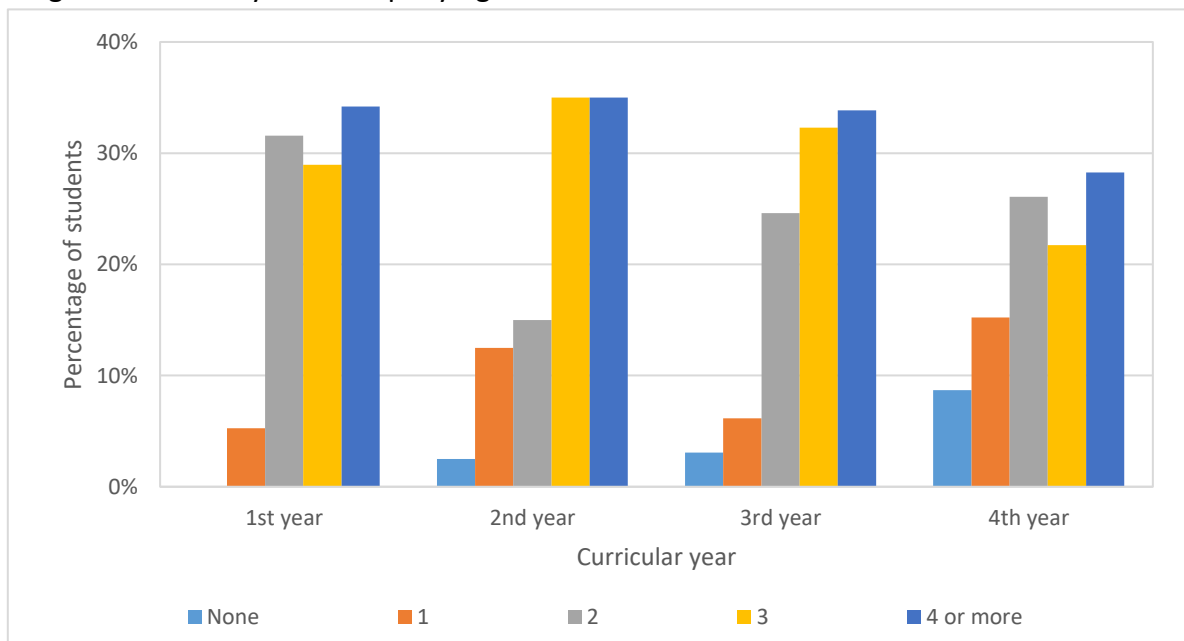
Curricular year	Significant and relevant increase	Significant and relevant decrease
1 <sup>st</sup> year	-	1
2 <sup>nd</sup> year	2	2
3 <sup>rd</sup> year	1	3
4 <sup>th</sup> year	4	1
5 <sup>th</sup> year	2	-
<b>Total</b>	9	7

These results indicate that 3rd year students may have faced more difficulties this semester, leading to greater incidence of courses with a significant and relevant decrease of the average mark. On the contrary, 4th year courses showed a particular tendency for an increase of the average mark. These results corroborate the conclusions previously drawn when analyzing [Figure 5](#) and [Figure 6](#), as the incidence of courses with a significant and relevant increase or decrease aligns with the fluctuations of the average mark throughout the curricular years. To further consolidate this conclusion, students were asked in how many courses they felt greater ease in accompanying the content and the unfolding of the course itself. The results are shown in [Figure 8](#).



**Figure 8:** Number of courses in which students felt greater ease by curricular year.

Considering that a typical semester consists of 5 different courses, these results once again confirm the conclusions drawn from Figure 6 the number of courses that students found easier than normal is relatively small, attesting to this semester’s higher level of difficulty in students’ eyes. In fact, about 86.3% of students felt a greater ease in accompanying the course in no more than 2 courses, less than half the number of courses in a semester. This percentage is the smallest in the 3rd year (83.1%), a plausible result given the particularly high perception of difficulty and tendency for the decrease in the average mark in 2019/2020. Perhaps a more elucidating analysis is applicable to Figure 9, which contrarily to Figure 8: Number of courses in which students felt greater ease by curricular year. shows the number of courses in which students felt greater difficulty in accompanying the content.



**Figure 9:** Number of courses in which students felt greater difficulty by curricular year.

As expected, the tendency of Figure 9 is inverse to that of Figure 8 students have felt greater difficulties in a higher number of courses. In fact, almost two thirds of the students (62.3%)

signaled 3 or more courses, this number being even higher (84.8%) if the analysis is extended to 2 or more courses. This last indicator is higher (though not the highest) in the 3rd year (90.8%), an expectable result given previous conclusions. Results from the 4th grade were the smallest (76.1%), again indicating that 2019/2020 was not particularly harmed by the distance learning methodologies and corroborating the preceding analysis.

In terms of categorization by thematic area, courses with a significant and relevant increase were divided as follows: 1 belonging to Drawing, Design and Manufacture, 1 belonging to Heat Transfer and Fluid, 2 belonging to Management, 1 belonging to Materials, 3 belonging to Applied Mechanics and 1 belonging to no specific thematic area. Considering courses with a significant and relevant decrease, 2 were signaled as belonging to Automation, 1 as belonging to Drawing, Design and Manufacture, 2 as belonging to Heat Transfer and Fluid, 1 as belonging to Management and 1 as belonging to Mathematics. [Table 4](#) summarizes these results.

**Table 4:** Distribution of courses with significant and relevant variations of the average mark by thematic area

Thematic area	Number of courses	Significant and relevant increase	Significant and relevant decrease
Automation	5	-	2 (40.0%)
Personal and Interpersonal Skills	-	-	-
Drawing, Design and Manufacture	3	1 (33.3%)	1 (33.3%)
Heat Transfer and Fluid	7	1 (14.3%)	2 (28.6%)
Physics	1	-	-
Management	5	2 (40.0%)	1 (20.0%)
Computer Science	2	-	-
Mathematics	2	-	1 (50.0%)
Materials	1	1 (100.0%)	-
Applied mechanics	6	3 (50.0%)	-
Production	1	-	-
Other	1	1 (100.0%)	-
<b>Total</b>	<b>34</b>	<b>9 (26.5%)</b>	<b>7 (20.6%)</b>

As shown, there is no thematic area with a clearly positive or negative balance in terms of number of courses with an increase versus number of courses with a decrease, with the exception for Automation and Applied Mechanics, for which students' marks were negatively and positively affected, respectively. Moreover, given the low number of courses lectured during the 2nd semester for each thematic area, it is difficult to support any conclusion. Therefore, it is reasonable to state that the analysis by thematic area does not show any

evident tendency of these courses with a variation of the average mark, meaning they occur with no particularly high or low incidence in any of the thematic areas.

The last step in this categorization of courses is their division by Master specialization. During the last three semesters of the degree, students choose one of five different Master specializations and, within each specialization, certain courses from a wide range of possibilities. Of the courses which registered a significant and relevant increase, 2 are not related to any specialization, 2 belong to Automation, 2 belong to Thermal Energy, 4 belong to Production, Conception and Manufacturing, 3 belong to Production Management and 2 belong to Structural Engineering and Mechanical Design. Of those with a significant and relevant decrease, 6 are common courses and only one belongs to a specialization, Production Management. [Table 5](#) summarizes these results.

**Table 5:** Distribution of courses with significant and relevant variations of the average mark by specialization

Specialization	Number of courses	Significant and relevant increase	Significant and relevant decrease
Common courses	16	3 (18.8%)	6 (37.5%)
Automation	6	2 (33.3%)	-
Thermal Energy	7	2 (29.6%)	-
Production, Conception and Manufacturing	7	4 (57.1%)	-
Production Management	7	3 (42.9%)	1 (14.3%)
Structural Engineering and Mechanical Design	6	3 (50.0%)	-
<b>Total</b>	<b>49</b>	<b>17</b>	<b>7</b>

An important aspect to mention is the fact that certain courses belong to more than one specialization, which results in an apparently higher number of courses. However, the courses in analysis are the same throughout the whole study. In terms of courses with an increase in the average mark, they are distributed almost uniformly throughout all specializations, with the exception for Production, Conception and Manufacturing, and Structural Engineering and Mechanical Design, with a slightly higher occurrence. It is, however, the analysis of the courses with a significant and relevant decrease that a clear tendency is evidenced: they occur almost exclusively as common courses. This may be justified by less flexibility in these courses' structure: having more students and, consequently, more professors involved, it becomes harder to implement adjustments facing this new distance learning situation. On the contrary, specialization courses tend to have fewer students and, therefore, these adaptations are streamlined. This may be pointed as one of the reasons for these results.

Even for those courses in which no significant or relevant variation of the average mark was detected, further analysis is possible. As in any data distribution, the variance, which evaluates the degree of deviation of the observations from its average value, can supply additional insight. In fact, of the 18 courses that fit in this category, 10 were characterized by a variance that was higher than in any of the three previous years. This indicates that, despite the average mark being essentially unaltered, the distribution of the marks was stretched into a wider value range. In other words, student ranking was more evident. On the contrary, only 2

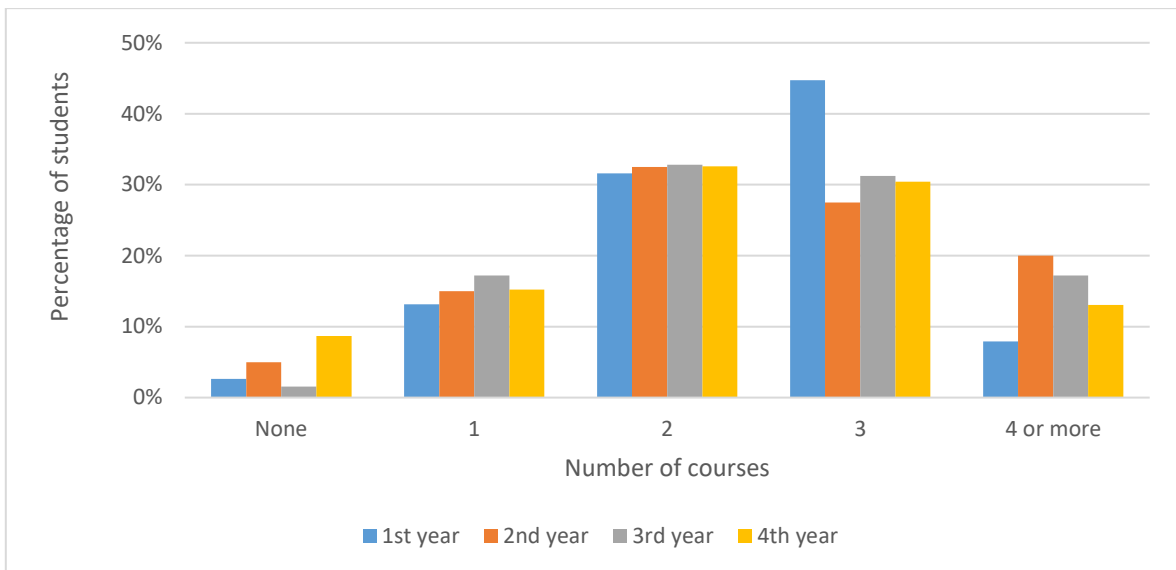
courses had a smaller variance than in previous years – indicating that all marks were concentrated around the average value and, therefore, student ranking was not as clear. Considering the 7 courses in which a significant and relevant decrease of the average mark was observed, this tendency is repeated: 3 courses with a higher variance against only 1 with a lower variance – again comparing with the three previous years. The latter group, representing the 9 courses which suffered a significant and relevant increase, this phenomenon is not visible: only 3 courses have a higher variance, while 3 show a lower variance than in previous years. This analysis is summarized in [Table 6](#).

**Table 6:** Variations of variance in courses' marks

Variation	Non-significant or	Significant and	Significant and	Total
	non-relevant variation	relevant decrease	relevant increase	
	18 (52.9%)	7 (20.6%)	9 (26.5%)	
<b>Higher variance</b>	10	3	3	16 (47.1%)
<b>Lower variance</b>	2	1	3	6 (17.6%)

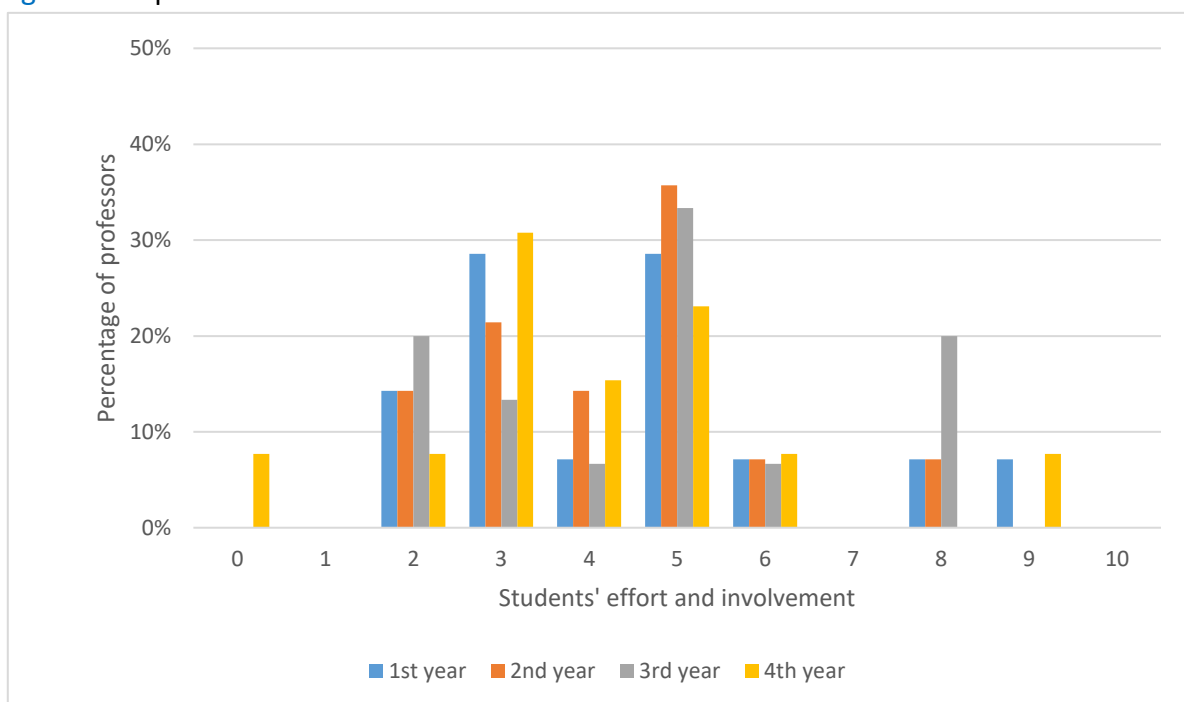
One of the main difficulties students face when a new professor oversees a certain course is the uncertainty regarding the evaluation methods. A new professor typically alters the exam structure, which may create an additional obstacle for many students who make exams from previous years a key element of their study. This year, as exam structures were changed in many courses due to the restrictions imposed on the duration of exams, this deciding factor led to a better distinction between students when it comes to the evaluation of their knowledge. Approximately half the courses (47.1%) presented a more homogeneous distribution of marks this year, which may be interpreted, as previously referred, as a clearer student ranking. This is visible in [Figure 1](#) and corroborates the previous result: the increased variance observed in approximately half the courses indicates a more uniform distribution of marks and, consequently, a clearer student ranking. The restriction imposed on the duration of present exams, which were limited to 90 minutes, may have contributed to this result as it tests students' ability to quickly think of a method to solve the question and arrive at an answer.

The construction of the questionnaires was planned to later allow for the comparison of the answers from both students and professors to similar questions. It is relevant to analyze both parties' opinion on each other's effort and involvement during this semester. Therefore, [Figure 10](#) shows the number of courses in which students felt that the accompaniment provided by professors in theoretical classes was adequate.



**Figure 10:** Number of courses in which students felt theoretical accompaniment was adequate.

Figure 10 indicates that in any year most students (over 80%) felt that the theoretical component of at least one course was insufficient or inadequate. In fact, only approximately half the students felt they received appropriate theoretical accompaniment for most courses – at least 3 courses, considering that a typical semester consists of 5 courses. Surprisingly, this value is the smallest (43.5%) in the 4th year, and the data indicates that 4th year students felt the most unaccompanied during this semester. On the contrary, 1st year students are the most satisfied with professors’ involvement in the theoretical component of the courses. To visualize professor’s perception of students’ effort and involvement in theoretical classes, Figure 11 is presented.

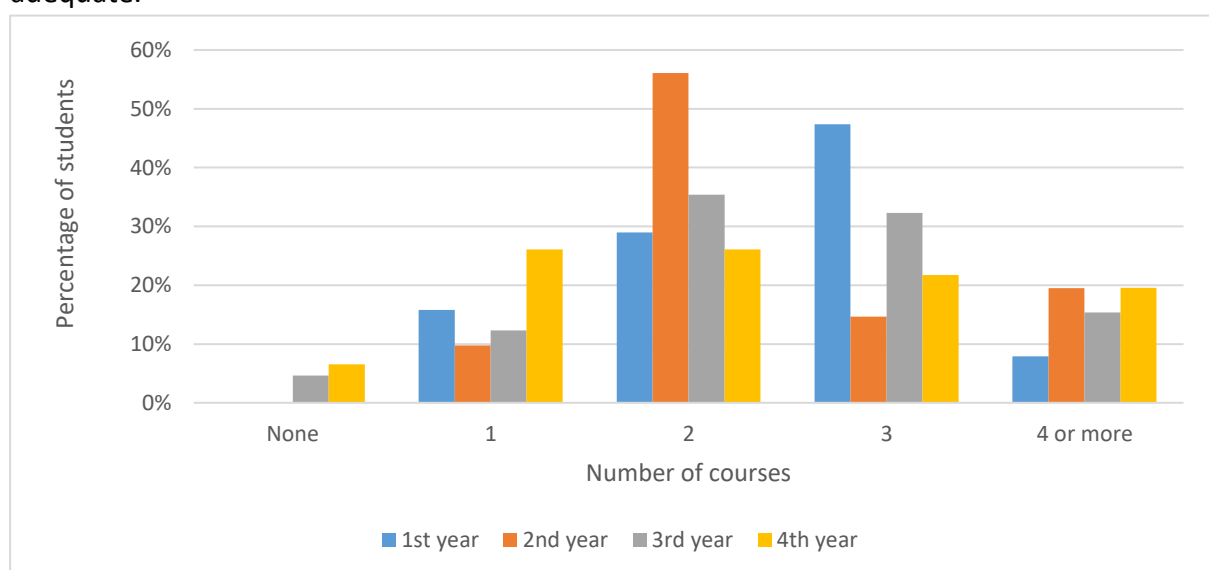


**Figure 11:** Professors' perception of students' involvement in theoretical classes.

The analysis of this graph together with the data on which it is based points to the conclusion that professors have perceived students’ involvement this semester to be less notorious than in previous semester, that is, when compared to a typical semester – reference level of 5. In

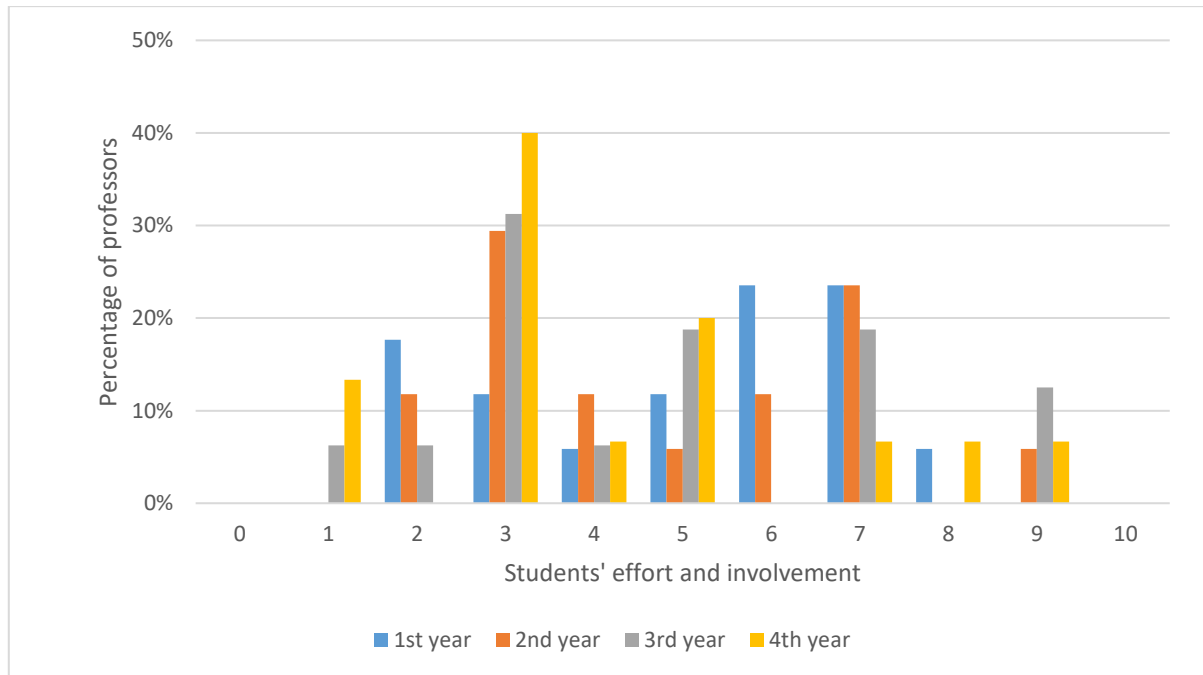


fact, for all 4 years the average value obtained from the questionnaire was lower than 5: 4.5 for the 1st year, 4.3 for the 2nd year, 4.7 for the 3rd year and 4.0 for the 4th year. Although 1st year students felt particularly well accompanied during the semester, their involvement in the different is not notoriously higher than other students', as perceived by professors. This is a positive aspect, leading to the conclusion that the student-professor dynamic functioned as expected and there was no mismatch between both parties' opinions. However, this is not true for 4th year students: although students felt less accompanied during the semester, professors' experience is that their level of effort was smaller than expected, as shown by the higher cumulative percentage curve. This situation is worrisome as it indicates that students and professors do not share a common opinion as to how the semester unfolded in terms of the theoretical component of 4th year courses. This analysis was repeated considering the practical component of the courses. Figure 12 now shows the number of courses in which students felt that the accompaniment provided by professors in practical classes was adequate.



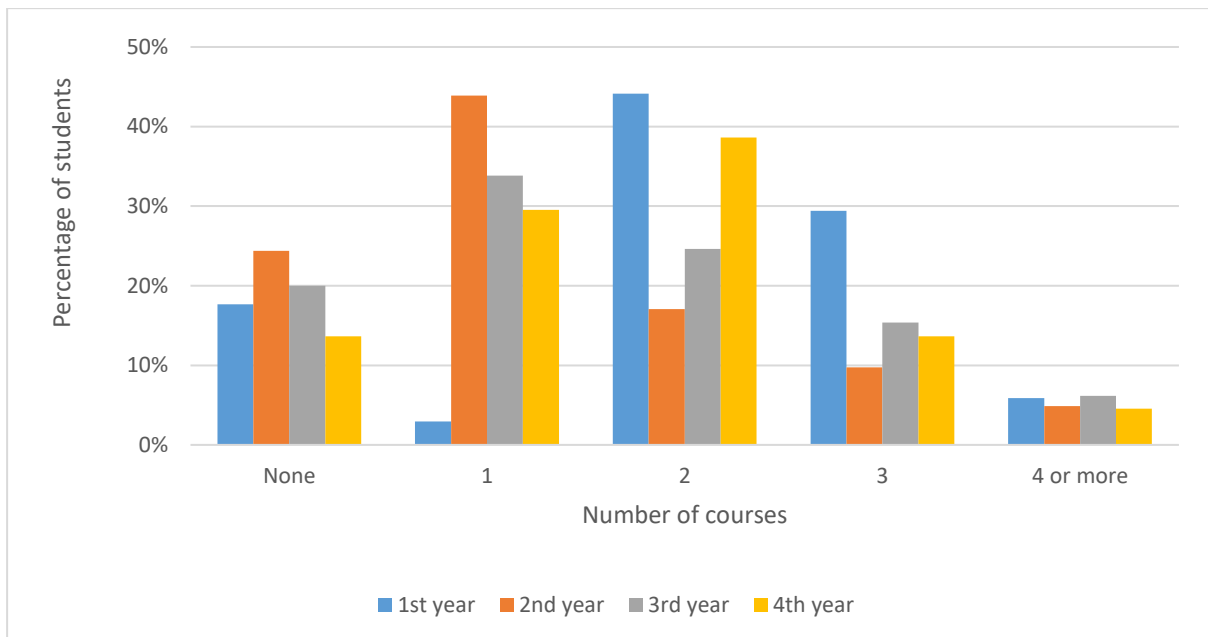
**Figure 12:** Number of courses in which students felt practical accompaniment was adequate.

Once again, 1st year students are overall the most satisfied with professor's work this semester, with over half the students (55.3%) signaling at least 3 courses in which they felt adequately supported. 4th year students are, as before, the least satisfied: only 67.4% of 4th year students felt adequate accompaniment in at least 2 courses, a low value when compared to other years (84.2%, 90.2% and 83.1% for the 1st, 2nd and 3rd year, respectively). When analyzing this semester and especially how smoothly it appears to have unfolded for 4th year students, it is rather surprising to conclude that these students feel the most unsupported in both theoretical and practical classes. Figure 13 illustrates professor's perception of students' effort and involvement in practical classes.



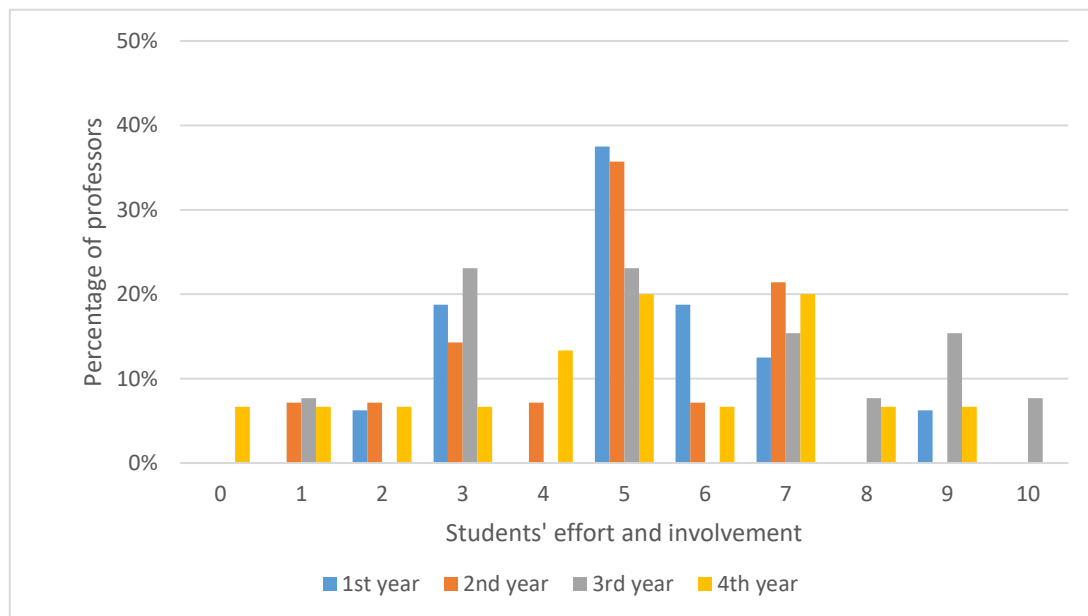
**Figure 13:** Professors' perception of students' involvement in practical classes.

Combining this visual information with the data with which it was built, it is noted that professors felt students were more involved in practical classes than in theoretical classes – average values of 5.1, 4.8, 4.8 and 4.2 for the 1st, 2nd, 3rd and 4th years, respectively. In fact, for 1st year, students' effort was more notorious for professors than in a typical semester. 1st year students' involvement was again perceived as the highest, in accordance with the fact that 1st year students felt the most accompanied. 4th year students' involvement in the courses was the lowest, a result that collides with the previous observation that 4th year students felt particularly unsupported during this semester. Finally, the project component of some courses was also addressed. [Figure 14](#) shows the number of courses in which students felt that the accompaniment provided by professors in projects was adequate.



**Figure 14:** Number of courses in which students felt project accompaniment was adequate.

The analysis of [Figure 14](#) must consider the fact that many courses do not have a project component in their evaluation process, which justifies, at least to some extent, the high incidence of “None” answers. Because of this, it is harder to draw any direct conclusions from [Figure 14](#). However, given the fact that courses with a project component are not the norm, an optimistic approach might allow for the conclusion that professor’s accompaniment of students in projects was rather positive. By analyzing professors’ opinions, as shown in [Figure 15](#), similar conclusions can be drawn.

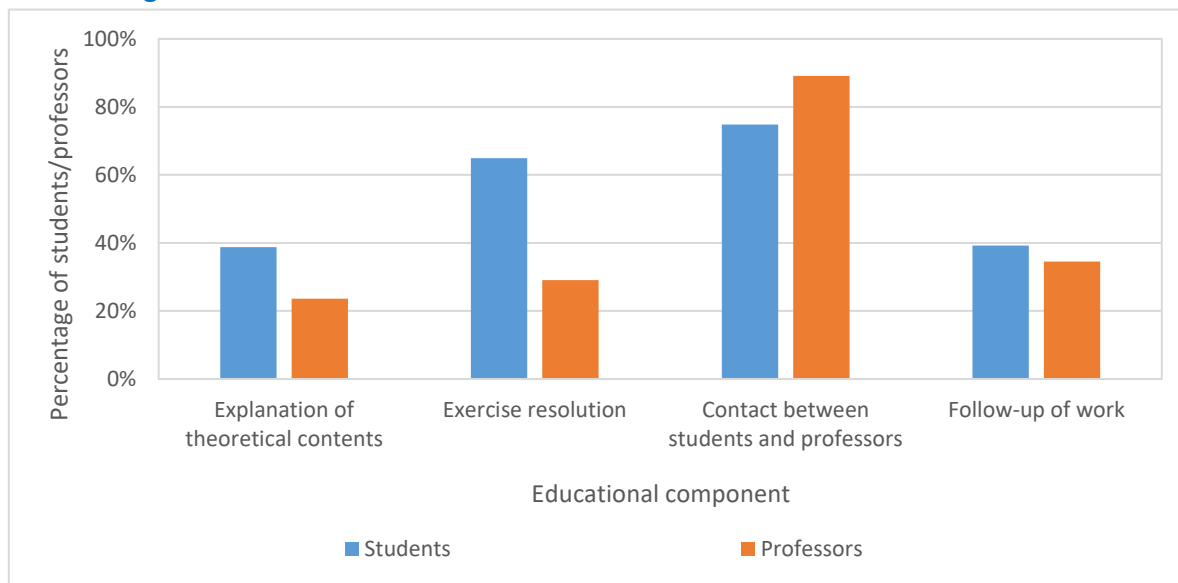


**Figure 15:** Professors' perception of students' involvement in projects.

In fact, the average value for all years was either very close to or higher than the reference level for a typical semester – 5.1 for the 1st year, 4.6 for the 2nd year, 5.8 for the 3rd year and 4.9 for the 4th year. It is relevant to mention that in both the 1st and the 3rd years the average value was even higher than the reference level. As far as projects are concerned, there is no particular year in which students felt a clear lack of accompaniment from professors. It can be

referred, though, that 3rd year students' effort was particularly evident to and valorized by professors, as seen in its lower cumulative percentage curve.

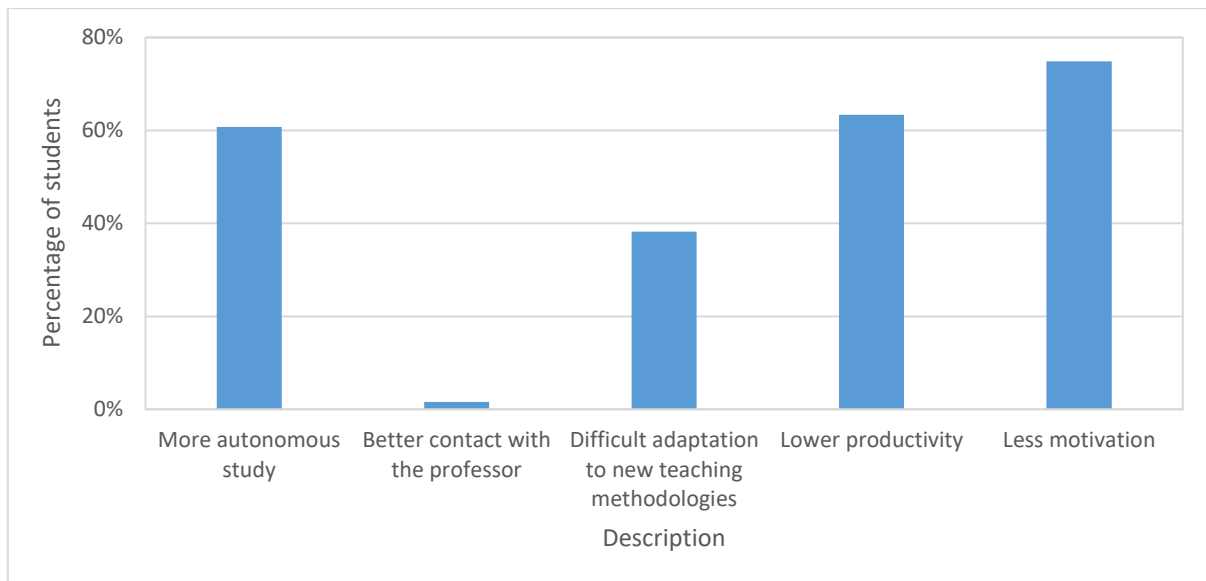
When asked to assess which components of the education process were particularly affected, students' and professors' opinions show reasonable agreement. Contact between students and professors was signaled by both as having been more affected (74.9% of students and 89.1% of professors). For students, exercise resolution took second place (64.9%), while for professors this was not very significant (29.1%). Students also felt that the follow-up of work (39.3%) and the explanation of theoretical contents (38.7%) were compromised, a concern shared with professors (34.5% and 23.6%, respectively). The summary of these results is shown in Figure 16.



**Figure 16:** Comparison between students' and professors' opinion on which educational components were most affected this semester.

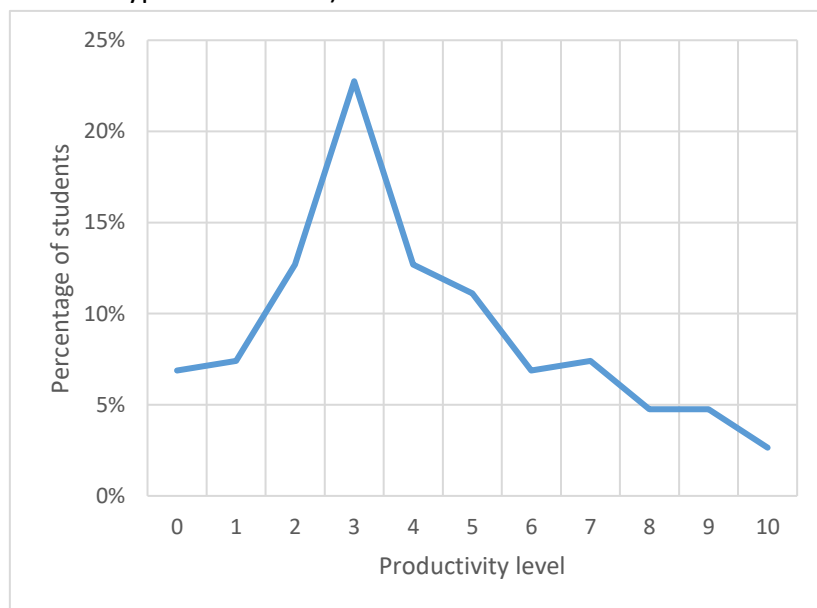
The coherence of students' and professors' opinions may indicate that this semester of distance learning posed similar difficulties to both parts. To overcome these common obstacles, the understanding that they are, in fact, common motivates unison work between the different faculty members.

A very significant percentage of students signaled a loss in productivity (63.4%) and motivation (74.9%), a rather unsurprising result given the circumstances of this semester. Uncertainty towards evaluation methods and even factors external to the faculty (psychological ones, for example) may justify these results. Despite these obstacles, the outcome is not entirely negative: many students (60.7%) were able to maintain a more autonomous study throughout the semester. Although this does not necessarily imply better marks, the ability to develop autonomous work is certainly an important skill for future engineers. New teaching methods were also an obstacle for students, leading to a significant percentage (38.2%) marking this as a suitable description of this semester. Figure 17 illustrates these results.



**Figure 17:** Students' description of this semester.

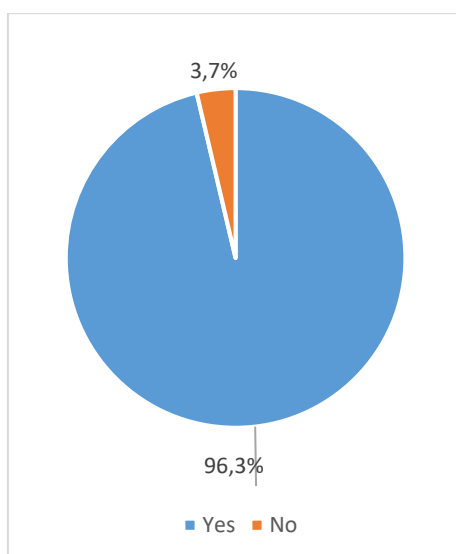
In accordance with these results, **Figure 18** shows students' evaluation of their own productivity and time management ability during this semester. Again, 5 was used as a reference level and answers ranged from 0 (much lower than in a typical semester) to 10 (much higher than in a typical semester).



**Figure 18:** Students' perception of own productivity level this semester.

These results validate the previous analysis, clearly demonstrating that on average students felt their productivity and time management ability was compromised.

It is also important to refer that most students (96.3%) felt that having access to recorded theoretical classes, a measure adopted in many courses, was beneficial. As previously mentioned, this allows for a greater flexibility when it comes to organizing one's schedule. Moreover, students can watch the lecture video at their own individual pace and even repeat a certain part to tackle a specific doubt, something that would make presential classes unviable. **Figure 19** illustrates the distribution of these percentages, undoubtedly showing that access to recorded theoretical classes was dominantly reviewed by students as positive.



**Figure 19:** Students' opinion on the benefits of access to recorded theoretical classes.

### Conclusions

This study identified a decrease on the global average mark (for all students and courses) during a distance-learning semester. This may appear to contradict the fact that the ANOVA procedure detected a higher number of courses with a statistically significant (and relevant) increase than with a statistically significant (and relevant) decrease of the average mark. However, most courses with an increase of the average mark are lectured during the 4th curricular year – given the structure of the degree, at this point students are already separated in different Master specializations, resulting in a smaller number of students in each course. For this reason, it is plausible that the global average mark decreased. The global mark decrease may be directly linked to the distance-learning methods, however external factors may be signaled. Firstly, students have faced increased stress and anxiety regarding the pandemic, which may have affected their academic success. Moreover, difficulty in adapting to the distance learning methods may also have been responsible for this decrease. Changes in routine, class dynamic, and exam structures, were necessary.

The effect of the pandemic on the degree was, in global terms, evidently negative, compromising students' academic success. However, this effect was not uniform: students in different curricular years felt different obstacles and to different extents. In many topics, students and professors felt similar difficulties, which is a positive aspect as it allows for an open dialogue between both parties to accurately identify and describe the obstacles and work towards a solution. This mindset is crucial as society may still witness a second wave of the virus or even the outbreak of a new pandemic. Both these situations will, once again, put the whole education system towards a great pressure to ensure quality education. Therefore, communication between all members of the education system may allow for something positive to result from this semester: a set of tools with which both students and professors can work to ensure quality teaching in a distance learning situation, should it ever again be necessary. However, in other matters students' and professors' opinions diverge. This mismatch is itself an obstacle in this distance learning method. As an example, in some cases students feel professors did not provide adequate support and feedback, whilst professors believe students were not sufficiently involved – when tackling these situations, it is harder to identify the root of the problem and delineate a possible solution.

Despite its clear negative impact on the education system, and particularly in this degree, this pandemic situation has forced the implementation of new teaching and evaluation methods, some of which may never have even been considered in a normal scenario. This created the potential for changes in the education system, but also many difficulties which will undoubtedly reappear in a new pandemic. This means that the education system has been given the opportunity to create solutions for these problems and that this pandemic may have a positive outcome.

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