Surviving and thriving: How changes in teaching modalities influenced student satisfaction before, during and after COVID-19

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This paper leverages analytics methods to investigate the impact of changes in teaching modalities shaped by the COVID-19 pandemic on undergraduate students' satisfaction within a Spanish brick-and-mortar higher education institution. Unlike research that has focused on faculty- or programme-level data, this study offers a comprehensive institutional perspective by analysing large-scale data (*N* = 83,532) gathered from satisfaction surveys across all undergraduate courses in eight faculties from 2018 to 2021. The longitudinal analysis revealed significant changes (*p* < 0.05) in satisfaction indicators, particularly overall satisfaction and perceived workload. During the emergency remote teaching period, there was a significant decrease in satisfaction and high levels of variability across courses. However, a year after emergency remote teaching, with increased implementations of technology-supported online and mixed teaching modalities, satisfaction measures not only recovered but exceeded pre-COVID levels in the aforementioned indicators when the teaching modality was fully co-located. The variability of answers also reached historical lows, reflecting more uniform student experiences. These findings highlight the resilience of educators and the current higher education system and suggest a capacity to learn and improve from disruptive pedagogical changes. The study also provides insights into how data analytics can help monitor and inform the evolution of teaching practices.

Implications for practice or policy
- Higher education institution administrators should improve the understanding of the effects derived from changes in their teaching and learning models, for example,
- in teaching modalities and related technology support.
- Student satisfaction data analytics offer useful indicators to study the impact of those effects.
- Higher education institutions should provide support for educators to ensure minimal deviations from expected averages of educational quality indicators regardless of the educators' capacity to adapt to changes in the teaching models.

Keywords: learning design, academic analytics, teaching modalities, emergency remote teaching, student satisfaction, quantitative, case study

Introduction

Student satisfaction with their teaching can be defined as the subjective evaluation of the different expectations and outcomes related to the educational process (Oliver & DeSarbo, 1988). In general, satisfaction can be measured as positive when the individual's perceived outcome meets their expectations. On the other hand, they will find dissatisfaction when their expectations surpass the perceived outcomes (Elliott & Shin, 2002). Satisfaction is commonly measured following one of two strategies: as a single overall satisfaction measure or a more specific multidimensional study. An overall satisfaction study attempts to summarise satisfaction into a single numeric score, while a survey oriented to attributes and factors will try to understand the relation between the variables that may influence satisfaction (Elliott & Shin, 2002).

Empirical studies have found various influential factors in student satisfaction. Social interactions with peers, course content, the quality of the teaching resources, the teaching quality, the technological resources and educational software used have been proven to significantly impact satisfaction (García-

Aracil, 2009). A longitudinal study in the United Kingdom revealed teaching quality and organisation and management as the main predictors of satisfaction (Burgess et al., 2018). In Denmark, the perceived value and quality of the software and the university's image were found to be antecedents of satisfaction (Shahsavar & Sudzina, 2017). Furthermore, students' satisfaction has proven to be strongly negatively correlated with dropout intentions (Duque, 2013) but positively correlated with personal motivation and learning commitment (Kuo et al., 2014). Even personal values such as loyalty were found as possible predictors, especially in online education (Pham et al., 2019). In recent years, the COVID-19 pandemic heavily impacted students' satisfaction with their academic work and lifestyle (Aristovnik et al., 2020; Kecojevic et al., 2020; Şimşek & Akün, 2022). There have been reports that changes in academic practices, social life, financial situation and emotional health could be found (Aristovnik et al., 2020) and the quality of resources and infrastructure, especially those related to information and communication technology (ICT), have a bigger effect on overall satisfaction (Baharuddin et al., 2022; Qekaj-Thaqi & Thaqi, 2021).

Regarding teaching configurations, co-located or face-to-face learning is only possible if the professor and student share the same physical space. On the other hand, distance online education has been enabled by ICT developments, allowing students to attend classes from different spaces at the same or different times. At the midpoint of the spectrum, mixed learning is the combination of presence and technology-supported education, including different kinds of blended learning, merging synchronous and asynchronous learning, co-located, online and hybrid learning (Cohen et al., 2020). Finally, emergency remote teaching (ERT) refers to the temporary measures regarding teaching and learning methods taken to maintain educational continuity. The health crisis of COVID-19 implied a sudden change in the teaching modality for brick-and-mortar higher education institutions (HEIs), at least partially, to a different mode (typically online or mixed) with ERT (Hodges et al., 2020).

The transition between these teaching modalities, from in-person to online and mixed learning, was often too quick and sometimes hard for educators because of the lack of preparation for several HEIs (Beardsley et al., 2021; Busuttil & Camilleri, 2020; Martin et al., 2022; Sahu, 2020). Studies about the impact of this emergency change of teaching modality showed that students reported being more satisfied with the courses that took advantage of real-time conferences, video recordings, presentations and written tasks, in that order, for their development (Aristovnik et al., 2020; Moreno Oliver & Hernández-Leo, 2020). However, there is still room for more studies describing the effects on student satisfaction caused by the changes in teaching modalities at the institutional level (Scaringella et al., 2021).

A single study conducted on the impact of pandemic-induced online learning covering 103 countries, scrutinising an array of topics from technology use and strategic planning to curriculum redesign, assessed student perceptions and the psychological impacts of this new learning environment (Zhang et al., 2022). The data revealed a concentration of research in medical and chemical education and frequently discussed or implemented instructional approaches including enquiry-based learning, discovery learning, hands-on learning and collaborative learning (Zhang et al., 2022).

Despite the breadth of this research, most studies have been limited to the programme or faculty level. For instance, Verde and Valero (2021) describes the case of two Spanish universities focusing on education and science degrees. Su et al. (2021) centred on medical studies in China exploring the most successful tools and platforms used during the pandemic and a general overview of the attitudes and perceptions of the students towards those resources. Bruscato and Baptista (2021) used an online survey to gather data about satisfaction from students and professors from universities in Brazil and Portugal during the pandemic, resulting in 225 answers mainly from students of the Bachelor in Letters (27%), Bachelor in Pedagogy (16%), Psychology (9%), Education (8%) and a 32% not reported. Iuliano et al. (2021) reported changes in the satisfaction level of the Sports Science programme from an Italian online university that typically accommodated a blended learning modality. Stickney et al. (2019) stated that at least for online education, satisfaction survey analysis typically consists of studies within a single faculty with multiple students. Additionally, Scaringella et al. (2021) pointed out that empirical research has no agreement on the results, reporting positive, negative and even insignificant findings about the impact of the teaching modality on learning and satisfaction.

The aim of this study is to advance the state of the art with the measured effects on the students' satisfaction in all the undergraduate programmes because of the modality changes derived from the COVID-19 crisis at the level of a top-ranked medium-sized brick-and-mortar public HEI in Spain. To this end, the study seeks to answer the research question: "How did changes in teaching modalities configurations before, during and after the COVID-19 pandemic impact students' satisfaction with their courses?"

The originality of the study lies not only in the new statistical insights about the changes in satisfaction through the most relevant teaching modalities implemented in recent years using reliable data but also in its scale at the level of a whole HEI gathering data for 4 whole years. To the best of our knowledge, single programme or faculty-scale studies prevail in the literature (Al Lily et al., 2020; Alzahrani & Seth, 2021; Amir et al., 2020; Baber, 2020; Cvijanović et al., 2021; Quezada et al., 2020), an exception being the Pekin University's case (Bao, 2020), which was primarily concerned only with online experiences.

This paper continues with an explanation of the data collection, followed by a description of the data cleaning pipeline and reliability assurance process. Subsequently, the findings of the analysis are presented, which includes an overview of overall satisfaction trends by question. A deeper comparison between overall satisfaction by the teaching modalities is presented using quantile analysis. With this information, the research question is answered by examining the changes in satisfaction across different teaching modalities and specifically comparing the same courses (same trimesters). Then, the results are contextualised with current literature. Finally, we provide conclusions and limitations of the study and suggestions for future research.

Methods

Data set description

The data set used in this study encompasses the responses from a 4-year institutional student satisfaction survey (from 2018–2019 to the 2021–2022 academic years). The data set consisted of 83,532 responses from undergraduate students. Each academic year is divided into three trimesters, resulting in a total of 12 trimesters over the 4 years. The trimesters are represented using the notation Ti, i = {1, 2, 3, …, 12} such that T1 stands for the first trimester of the 2018–2019 academic year and T12 stands for the third trimester of the 2021–2022 academic year (see Figure 1).

Figure 1. Timeline tracking the teaching modalities by academic year and academic trimester
Note. The temporal frame of the analysis, on the bottom, is the academic year. In the middle, the sequential trimester code uses the notation (Ti) for all the periods under study. At the top, there is the prevailing teaching modality for the given academic periods.

From the first trimester of 2018–2019 (T1) to the second trimester of 2019–2020 (T5), learning activities at the HEI were carried out according to the pre-COVID course design, which strongly emphasised the co-located learning activities and on-site classroom interactions. However, with the onset of the COVID-19 pandemic in the third trimester of 2019–2020 (T6), ERT was activated, making online activities the central focus of the learning design for direct instruction and interaction with the professors. During the first and second trimesters of 2020–2021 (T7–T8), a mixed strategy was promptly implemented, aligning with government restrictions, with fully online teaching as the primary learning modality. The mixed modality was maintained during the third trimester of 2020–2021 (T9) but with a gradual return to on-site interaction while allowing for remote participation by some students. From the first trimester of 2021–2022 (T10–T12), co-located learning was encouraged, utilising large classrooms to commit to physical

distancing requirements. The digital technologies used were essentially a learning management system (Moodle) and videoconference systems (Collaborate, Zoom).

The university assesses students' satisfaction regarding their learning experience in each course at the end of every term using a survey that consists of four questions related to the course and two about the professor(s). The survey was co-designed several years ago by a university committee including the stakeholders and considering expert opinions based on a previous survey in use for more than 15 years in this HEI. The survey was made. The results from the questionnaire are considered for teaching evaluation purposes in the institution. Table 1 contains the actual questions used in the satisfaction survey to assess different aspects of the teaching process (Column 1), the summarised main topic addressed by the question (Column 2) and the coding scheme that used throughout the study,with each code composed of three letters referencing the main topic (Column 3).

Table 1
Student satisfaction survey

Question	Topic	Code
The contents taught within the subject and the competencies worked are adjusted to what the teaching plan says.	Teaching plan contents & competencies	PLN
The teaching methodologies used (design of class sessions, activities to be carried out by students and teaching materials used) have helped me in the learning process.	Teaching and learning methodologies	MTD
The volume of work required is adapted to the credits of the subject.	Overall perceived workload	WLD
In general terms, I am satisfied with this subject.	Overall satisfaction (subject)	SBJ
The teacher has adequately fulfilled their teaching obligations (teaching plan, punctuality, attention to students, etc.)	Professor obligations	OBL
I am satisfied with the teaching received.	Overall satisfaction (teaching)	TEA

Note. The coding scheme refers to the main topic addressed by the question. PLN: teaching plan contents & competencies, MTD: teaching and learning methodologies, WLD: overall perceived workload, SBJ: overall satisfaction (subject), OBL: professor obligations, TEA: overall satisfaction (teaching).

Raw data was facilitated by the HEI, based on the results of the satisfaction survey on undergraduate students and in accordance with the data protection obligations of the institution. Original data (N = 83,532) included information about the course (e.g., period, faculty, group) and relative to the survey itself (one row per question and per group). The average satisfaction is presented on a scale from 0 to 10 for each question, with 0 meaning *complete dissatisfaction* and 10 meaning *complete satisfaction*.

Data pre-processing

Data pre-processing began with the unification of separate and non-homogeneous spreadsheets (one generated per academic period, which explains the diversity in formats and contents), followed by selecting relevant features essential to addressing the research question, including course identifiers, question identifiers, averages, number of enrolled students and respondents per course.

Next, the pipeline addresses data quality by eliminating missing or broken records (less than 1%) and standardising data set names. To protect the identities of professors and students, anonymity measures were implemented. The process continued by removing irrelevant, unusable and duplicate data (less than 1%) before systematically imputing the required fields. As a final step, the pipeline applied a reliability filter called reliability assessment score (RAS) to produce a clean dataset, after performing all the steps, the data set went from N = 83,532 to N = 18,459 not null and unique registers. The data pre-processing pipeline applied before the data analysis is summarised in Figure 2.
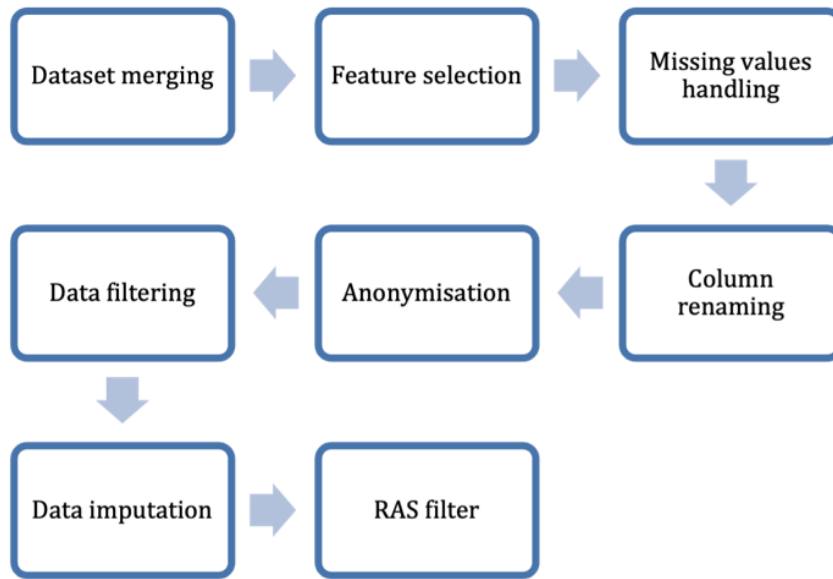
Figure 2. Complete data pre-processing pipeline applied to extract the relevant information for the study

Low response rates from students are the main concern in the analysis of satisfaction surveys (Capa-Aydin, 2016; He & Freeman, 2021). A low response rate would imply an underrepresentation of the population and affect the assessment's quality. To prevent this, only the courses with a sufficient number of enrolled versus number of respondents ratio were considered for the analysis. For that, a filter based on the RAS index (Scheaffer et al., 2011) was applied to the input data set defined as follows.

The RAS index is defined as the bound of error of estimation; we followed the conservative recommendation of setting the standard deviation parameter to 1.1 (Scheaffer et al., 2011) (1).

$$RAS = 2\sqrt{(\frac{1.1^2}{n}) * (\frac{N-n}{N})} \qquad (1)$$

If:

$0 \leq RAS < 0.25$ is considered to have a good number of responses.
$0.25 \leq RAS \leq 0.5$ is considered to have enough responses.
$RAS > 0.5$ is considered to have an insufficient number of responses.

After the application of the RAS filter, the data distribution changed, preserving only the courses with the highest numbers of enrolled students and those with the greatest number of respondents. In total, 18,459 samples were kept. The mean of the enrolled per course went from 66.25 to 99.75, and the mean of the total respondents per course increased from 13.12 to 31.73. Finally, cleaned data was sorted by trimesters from the first term of 2018–2019 until the third trimester of 2021–2022 for a total of 12 periods under study. To facilitate tracking through the analysis, the trimesters were enumerated from T1 to T12 (refer to Figure 1) to correspond with the changes in teaching modality.

Data analysis process

To address the research question, we conducted a series of interrelated analyses. The Satisfaction by question section presents the fundamental descriptive statistics for each question, offering an overview

of student responses by analyzing measures of central tendency and dispersion at the institutional level. In the Quantile analysis by teaching modality section, we present a quantile analysis to gain insight into the distribution of student satisfaction scores across various percentiles, enabling a comparison of satisfaction levels across four different teaching modalities: co-located pre-COVID learning, ERT, mixed teaching and co-located post-COVID learning. We also calculated the interquartile ranges (IQR) to evaluate the spread of satisfaction scores within each modality. To complete the insights obtained from the quantile analysis, a comparison among teaching modalities using the kernel density estimator (KDE) curve as a reference is also presented.

Finally, as shown in the Satisfaction evolution by teaching modality section, we carried out a detailed comparison of third-trimester courses across these four teaching modalities, allowing us to compare the ERT online period (3rd trimester of 2019–2020) to the same courses offered in other modalities. It is important to note that all statistical tests were performed using a significance level of $p < .05$, and we report only effect sizes with a Cohen's *d* greater than .20.

Ethics declaration

This project has benefitted from the oversight and support of the data protection officer of the university where the research was carried out, ensuring that the methods and practices involved complied with applicable regulations and ethical guidelines.

Results

Satisfaction by question

To contextualise the results regarding the research question, first, we present the statistical distribution of each question in the survey (see Table 1 for coding reference). The question with the lower average score was the MTD question (*M* = 6.80, SD = 1.57) followed by the overall subject satisfaction SBJ (*M* = 6.90, *SD* = 1.55) and the highest average score was PLN (*M* = 8.15, SD = .99). Regarding the dispersion of the data, PLN also was evaluated more consistently by the respondents compared with the other questions (*SD* = 0.99) and TEA, with the highest standard deviation showing great variability in the student experiences on this topic (*SD* = 1.70). The distribution of satisfaction per question is shown in Figure 3.
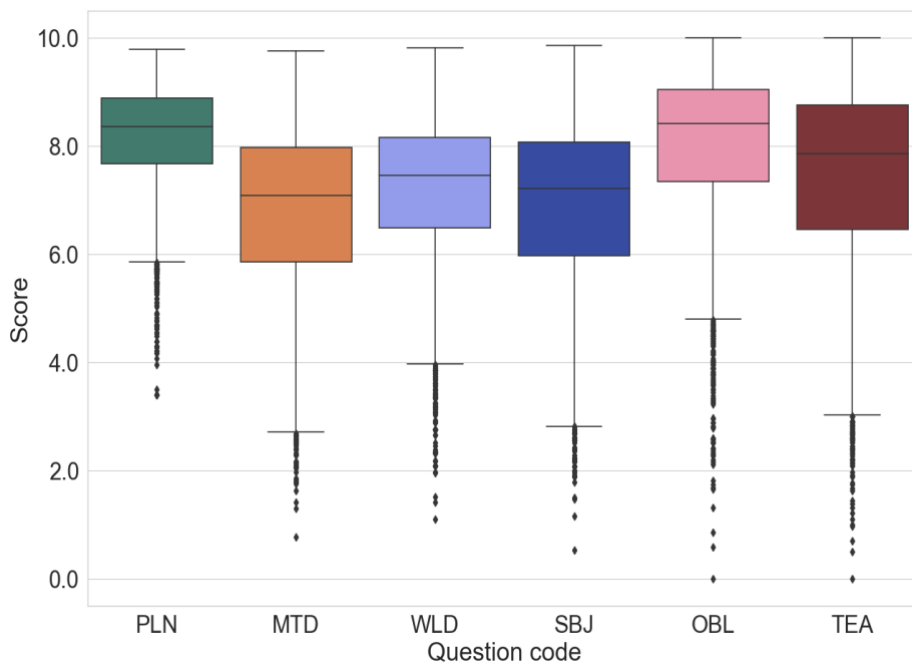

Figure 3. Distribution of the satisfaction score reported for each question on a scale (0–10)

In general, all the items were positively rated (*M* > 6.80). The analysis also shows that the overall satisfaction assessment related to the professor assessed by the TEA question always scored better than the one related to the course itself. Regarding SBJ, this question reflected the overall perceived satisfaction of the students for a given course. The statistical distribution of the responses received for SBJ by teaching modality is presented in Table 2.

Table 2
Data distribution by teaching modality

Teaching modality	Number of respondents	Overall satisfaction mean (SBJ)	Overall satisfaction SD (SBJ)
Co-located learning pre-COVID	5310	6.9	1.6
ERT online	1215	6.4	2.0
Mixed teaching	2992	6.8	1.8
Co-located learning post-COVID	8942	7.1	1.3

Quantile analysis by teaching modality

The data distribution presented in Table 2 showed that the overall satisfaction average decreased during ERT online period, returning to near the pre-pandemic values in the mixed teaching periods, improving even further during the post-COVID times surpassing the pre-COVID co-located learning values. Also, there was a high divergence in opinions from students about their satisfaction during ERT online and mixed teaching (SD in Table 2) and comparatively more homogeneous answers in the assessment during post-COVID. Figure 4 focuses once more on the overall satisfaction with the subject SBJ and presents a quantile analysis that confirms this observed trend.
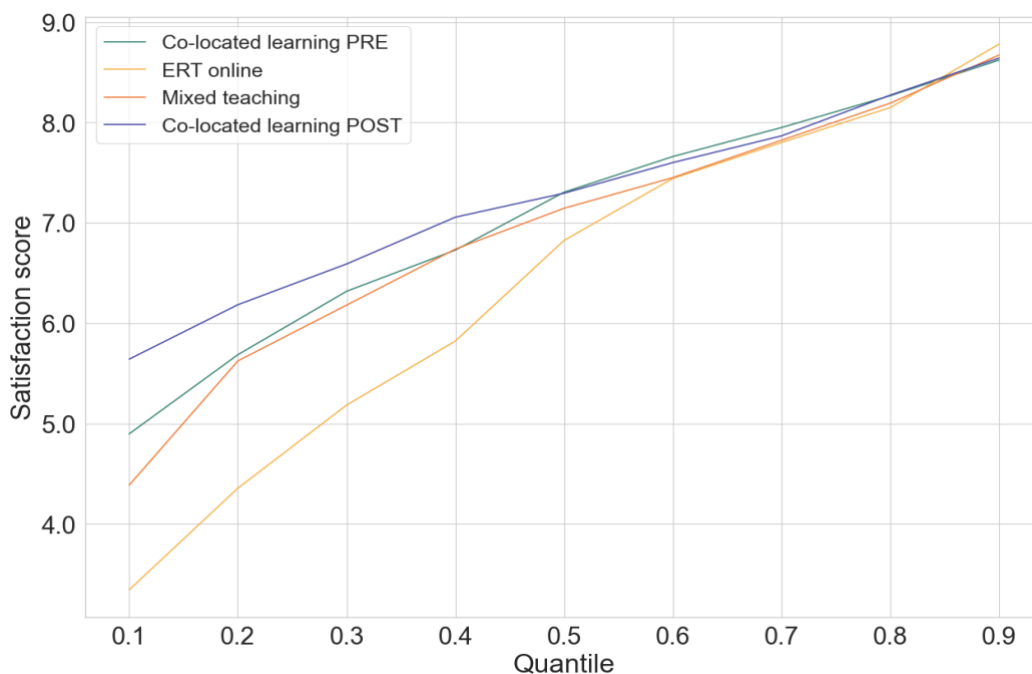

Figure 4. Visual quantile analysis for Question 4 SBJ regarding the overall satisfaction with the subject

The quantile analysis reveals a general trend of increasing satisfaction scores across all percentiles for each teaching modality. This suggests that a greater proportion of participants reported higher levels of satisfaction, particularly for the co-located post-COVID learning modality, which exhibited the highest score until the 60th percentile among all modalities. Furthermore, to examine how satisfaction has evolved across different modalities, the median (quantile 0.5) scores can be employed as an indicator of the central tendency within the data. The analysis indicates that at this level of aggregation, satisfaction

variations between these teaching modalities could be appreciated with the ERT online modality presenting the lowest satisfaction score, and the co-located post-COVID learning modality reaching the highest score. This difference is accentuated until the 60th percentile (quantile 0.6) also showing different increasing rates for each teaching modality, especially for mixed teaching. Lastly, the similarities in the trend between co-located pre-COVID learning modality to the co-located post-COVID learning can be observed but will require further detailed analysis to elucidate.

For a further analysis of the data, we can calculate the interquartile range (IQR) for SBJ among each modality, which gives us an idea of the spread of the satisfaction scores. Co-located learning pre-COVID has an IQR of 2.13, indicating a moderate spread of satisfaction scores. ERT online has the highest IQR of 3.06, suggesting a larger spread of satisfaction scores, which implies more variability in the participants' responses. Mixed teaching has an IQR of 2.38, indicating a moderate-to-high spread of satisfaction scores. Lastly, co-located learning post-COVID has the lowest IQR of 1.86, suggesting that satisfaction scores in this modality are more tightly grouped, with less variability. Although the results are not displayed to keep the text concise, this trend pattern is repeated throughout the six questions.
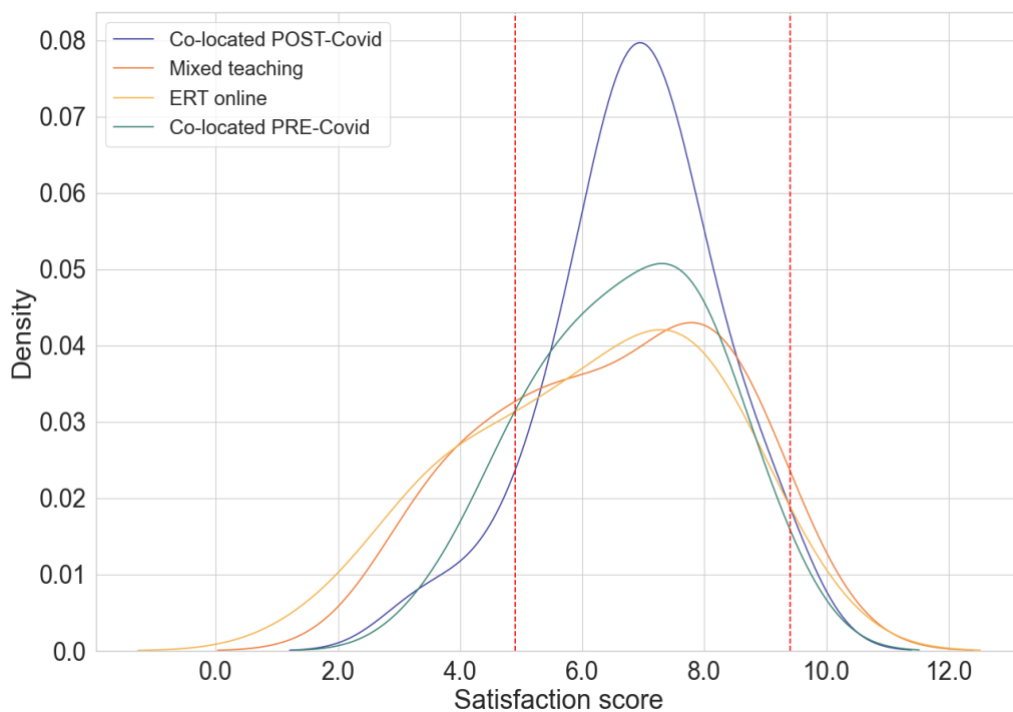

Figure 5. KDE for a stratified sample (*N* = 150) of the four teaching modalities under study
Note. Red dashed lines were manually added to mark points of interest where the overall trend changes.

Regarding the overall satisfaction question SBJ, a comparison of the KDE curves provides valuable insights into the distribution of student satisfaction scores (Figure 5) and demonstrates how these modalities may have influenced satisfaction levels during the COVID-19 pandemic. The co-located post-COVID modality exhibits the highest overall satisfaction levels, with a peak satisfaction score at 6.93. Respondents are highly concentrated between satisfaction scores of 4.9 and 9.4, as indicated by the red dashed lines, confirming lower variance in the assessment. Co-located pre-COVID exhibits a similar behaviour but with a slightly lower global peak. Conversely, ERT online and mixed teaching densities are more evenly spread across the satisfaction scores, indicative of higher variance. A significant proportion of the population assessed these periods with lower values between 0.0 and 5.8, which supports the insights derived from the analysis presented in Figure 4. Finally, beyond the second red dashed line (satisfaction > 9.4) and focusing on the highest values assessed by students, the trend reverses, with mixed teaching and ERT online modalities being ranked highest by these extreme values. Further discussion about this phenomenon will be presented in the Discussion section.

Satisfaction evolution by teaching modality

A comparison of the evolution of student satisfaction levels through the various phases of the pandemic reveals some patterns regarding the distribution of the data (Figure 6). To ensure the comparability and reliability of the results, only trimesters where the same subjects (N = 187) were taught were taken for reference, (T3, T6, T9, T12). These third trimesters of each academic year were selected to include the ERT online period in the comparison, providing a more comprehensive overview of student satisfaction levels throughout the various teaching modalities.
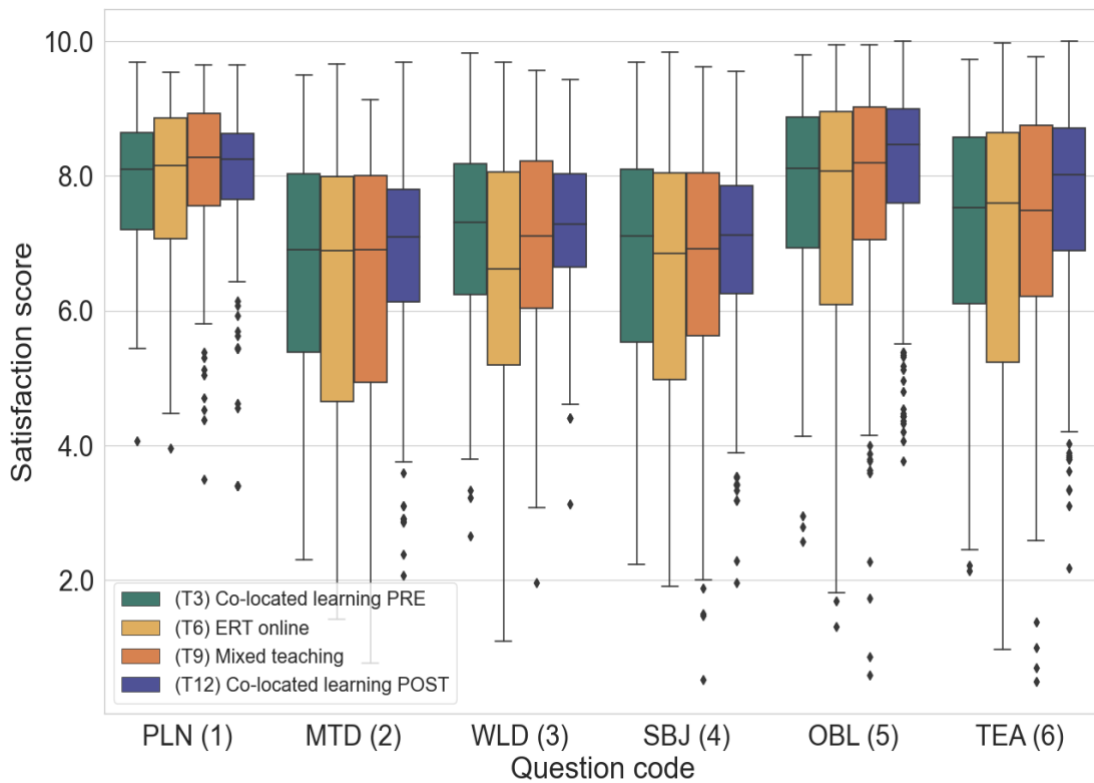

Figure 6. Visualisation of the changes in the distribution of satisfaction by teaching modality for each question
Note. To ensure comparability, this plot is presented for all the subjects taught in the third period of the academic year.

This plot presents a clear increase in the standard deviation for all the questions when comparing the co-located pre-COVID period to the ERT online one. Besides this, SBJ displays behaviour consistent with the analysis presented in Figures 5 and 6, having closer averages between the co-located modalities concerning the ERT online and mixed teaching ones. WLD showed a statistically significant decrease in the average from the co-located pre-COVID period (M = 7.05, SD = 1.39) to the ERT online period (M = 6.45, SD = 1.86), (p < .05). Between ERT online and mixed teaching periods, as mixed teaching methods emphasising online learning became established, the analysis shows significant improvements (p <. 05) in the average satisfaction in PLN, MTD and WLD, but on the other hand, there was a slight decrease for SBJ, OBL and TEA. Additionally, the dispersion for each question showed lower values between these periods. Finally, the changes from mixed teaching compared to co-located post-COVID teaching were always positive (higher values for average and lower values for standard deviation) for every question (clearly summarised in the overall questions SBJ and TEA); however, the measured effect size was small (d = .26). In the long term, there was also a notable improvement in the average and standard deviation from the co-located pre-COVID period (M = 7.47, SD = 1.5) to the co-located post-COVID period (M = 7.72, SD = 1.23).

Statistical inference analysis

Statistical analyses, including one-way ANOVA and Tukey's honestly significant difference tests, confirmed the observed trends in satisfaction when comparing the third trimester across the academic years (Figure 6). One-way ANOVA results indicated small but significant effects ($\eta^2 \leq 0.020$) on satisfaction with the teaching plan contents PLN: $F(3, 932) = 4.73$, ($p = .00276$); teaching-learning methodologies (MTD): $F(3, 931) = 6.35$, ($p = .00029$); and overall subject satisfaction (SBJ): $F(3, 932) = 6.15$, ($p = .000384$). A slightly greater effect ($\eta^2 \leq 0.045$) was observed on the perceived workload (WLD): $F(3, 932) = 14.23$, ($p < .00001$); professor obligation fulfillment (OBL): $F(3, 1119) = 16.73$, ($p < .00001$); and overall teaching satisfaction (TEA): $F(3, 1119) = 13.69$, ($p < .00001$). Tukey's honestly significant difference post hoc tests underscored significant improvements in satisfaction from the ERT period to the post-COVID period, with the most substantial increases noted from T6 to T12 across PLN ($p = 0.0022$), Similarly, MTD saw a meaningful increase in satisfaction from both T6 to T12 ($p = 0.0014$) and T9 to T12 ($p = 0.0114$). Lastly, overall satisfaction with the teaching received TEA markedly improved from T3 to T12, ($p = 0.0016$), with similar significant enhancements from T6 to T12, ($p = 0$); and from T9 to T12, ($p = 0.0011$), despite initial decreases in other categories. These findings highlight a general trend of recovering (and even surpassing) student satisfaction as institutions transitioned back to co-located post-COVID teaching modalities.

Discussion

Measuring students' satisfaction regarding their experience with courses is not an easy task. Because of the usual limitations in logistics and time, HEIs often distribute feedback questionnaires to students during the course, and those instruments are used as a proxy for measuring student satisfaction (Wilkins & Stephens Balakrishnan, 2013). Considering that, the literature shows mixed results regarding the changes in the measured satisfaction around the pandemic years. Some studies have reported that satisfaction during the pandemic was not significantly impacted for the worse in countries used to online or mixed learning (Abdull Mutalib et al., 2022; Moreno Oliver & Hernández-Leo, 2020; Montero et al., 2020). Conversely, students with limited resources and lack of connectivity and living in remote or rural areas reported being unsatisfied with the changes towards online education (Aristovnik et al., 2020). In this study, we focused on a public HEI that is reasonably well equipped in terms of digital infrastructure in a developed country with easy Internet access. As a result, any changes in student satisfaction levels reported are unlikely to be influenced by a lack of technological infrastructure or related issues. Instead, these changes are more likely to be associated with pandemic-induced changes in teaching methodologies and students' equipment and lifestyles. However, it should be noted that we did not explore the effect of students' quality access to physical and digital infrastructure or the changes in student lifestyles in depth, as these are beyond the scope of this article.

However, in light of recent findings (Guppy et al., 2022), the pandemic-induced shift to ERT seems to have set a new norm for education. Data from interviews and questionnaires involving various groups, including college and university educators, students, senior administrators and instructional design specialists across six countries on four continents, suggest that the majority anticipate more hybrid instruction post-pandemic, with a modest increase in fully online courses (Guppy et al., 2022). It is worth noting that students expressed more scepticism about future changes than the other groups, emphasising the need for careful consideration and management of students' expectations and experiences as we move forward. Furthermore, there is little expectation across all respondent groups for a revolutionary shift in online or digital learning. This suggests that, despite the drastic changes imposed by the pandemic, the evolution of digital learning in higher education may continue more gradually and more slowly.

The present study measured students' satisfaction based on a six-question survey. Two questions assessed the fulfilment of expectations compared with the teaching plan, one question measured the perceived workload, another one measured the overall satisfaction with the course and the remaining two questions evaluated the professor's obligations and student satisfaction with teaching. In comparison, Wach et al. (2016) used a 10-question satisfaction survey to assess three dimensions of student satisfaction (satisfaction with study content, satisfaction with the conditions of the academic

programme and satisfaction with the ability to cope with academic stress). In parallel, Sirgy et al. (2010) broke down satisfaction into four dimensions (satisfaction with facilities and services, satisfaction with academic aspects, satisfaction with social aspects and satisfaction with college life). In contrast with these direct approaches, students' satisfaction can be measured indirectly through a multidimensional service quality survey SERVQUAL (Alsheyadi & Albalushi, 2020), which assesses five dimensions (tangibility, reliability, responsiveness, assurance and empathy).

Considering that, our findings are more in line with the findings from recent studies that have shown that the COVID-19 pandemic had a significant impact on how students perceived how HEIs deliver their courses (Al Lily et al., 2020; Ali, 2020; Taylor et al., 2020). The shift to ERT in response to the pandemic has posed significant challenges for students and faculty members, leaving many of them unprepared and struggling to adapt to the new learning environment (Bozkurt & Sharma, 2020; Marinoni & van't Land, 2020). These changes implemented since the ERT period negatively impacted overall satisfaction and perceived workload, which is consistent with studies that have highlighted the negative impact of the COVID-19 pandemic on students' mental health and well-being (Husky et al., 2021; Singh et al., 2021). Also, the rapid shift to remote learning has resulted in students feeling isolated and disconnected from their peers and faculty members and the increased workload associated with the learning design changes has resulted in many students feeling overwhelmed and stressed (Xu & Wang., 2023).

However, as shown in the results, satisfaction levels (which were relatively high in the pre-COVID era) tended to return to these levels after the ERT period, which is consistent with the expectations of other recent studies that have highlighted the potential strengthening of the online and mixed learning after the pandemic (Kamal et al., 2020; Rahmani & Samira Zitouni, 2022). Although the rapid shift to remote learning has posed significant challenges, it has also presented new opportunities for HEIs to innovate and improve their delivery of courses.

Focusing on the results of the analysis, overall satisfaction measured by the fourth item of the survey SBJ does not show significant changes between the transition from one period to the next one. However, when the ERT trimester is compared to the "new normality" equivalent, the study found a significant improvement in the average assessment of satisfaction. Moreover, it is noteworthy that there is a generalised decrease in the dispersion of the answers for this item as well as improvements in satisfaction and less dispersion in the ratings for all the other items. This shows that teachers possibly improved their overall teaching skills (Beardsley et al., 2021) and methodologies as well as the quality of their material (e.g., to make it suitable for remote synchronous or asynchronous teaching, Quezada et al., 2020). In fact, these improvements have been recognised by students in their satisfaction ratings for the specific items MTD, OBL and TEA.

In terms of satisfaction with the perceived workload WLD, the sudden shift to remote teaching and learning due to the pandemic was a significant source of stress for students (Aristovnik et al., 2020). However, based on our data, it appears that teachers were able to adjust their methods and approaches in the following academic year (2021–2022) resulting in increased satisfaction levels for two trimesters, surpassing even the pre-pandemic levels. This suggests that after an experimental year, teachers were able to find effective ways to balance academic requirements with the workload, resulting in more satisfied students. It should be noted that this study did not control for variables such as age, disabilities or technical background, which have been found to have an impact on perceived workload in previous studies (Mather & Sarkans, 2018). Further research is needed to explore the impact of these variables on satisfaction with workload among students.

Due to the size and complexity of the original data set, the use of contemporary data analytics techniques played a fundamental role in this study. These techniques were particularly useful in creating a standardised workflow that managed complex, diverse data sources. This workflow unified and processed the data, extracting meaningful information for subsequent analysis and presentation, thereby enabling replication and scalability of the process. However, there are challenges to consider. Despite the lack of large-scale studies and real-world implementation issues of learning analytics-based processes

(Hernández-de-Menéndez, 2022; Quadri & Shukor, 2021), there are high expectations about the potential benefits for stakeholders. Success hinges on properly addressing common issues regarding data privacy, infrastructure, trustworthiness, result accuracy and interpretability (Caspari-Sadeghi, 2023; El Alfy et al., 2019). Finally, the results of this study may serve as an exemplary case, illustrating how learning analytics can be leveraged to enhance understanding and inform decision-making in contemporary higher education through these automated data analysis workflows.

Conclusions

The objective of this study was to explore how changes in teaching modalities affected students' satisfaction before, during, and after the COVID-19 pandemic taking advantage of the contemporary data analytics techniques that enable the possibility of studying a big volume of data with relatively low computational resources. The data analytics techniques applied were fundamental in developing a standardised workflow for managing complex, diverse data sources, unifying and processing the data and extracting meaningful information for subsequent analysis and presentation, allowing the process to be replicated and scalable. The data set consisted of an institutional six-item online survey collected over 4 years, which assessed various aspects of teaching and learning, such as contents and competencies, teaching-learning methods and resources, perceived workload, professor obligations and overall satisfaction with the teaching (Table 1). The major findings of this study can be summarised as follows:

Firstly, our descriptive statistics and quantile analysis highlighted the variation in student satisfaction levels across different teaching modalities. The ERT period had the lowest satisfaction scores, while the co-located learning post-COVID modality recorded the highest satisfaction levels. This finding confirms other findings (Aristovnik et al., 2020, Baharuddin et al., 2022; Qekaj-Thaqi & Thaqi, 2021) expressing that the online and mixed teaching methods implemented during the pandemic may not have provided optimal learning experiences for all students, with some students preferring the traditional co-located learning environment. Interestingly, this was broadly studied in developing countries, but this is one of the first studies to confirm the phenomena in a developed country.

Secondly, the literature suggests that students' overall satisfaction with teaching during the pandemic and ERT was diminished to some extent but varied depending on the specific circumstances and factors involved (Fuchs & Karrila, 2021; Wilhelm et al., 2022; Yekefallah et al., 2021). Regarding this, for the HEI under study, it is noteworthy that while most students expressed dissatisfaction with this modality, a minority of the population found this period extremely satisfying, even compared to the co-located teaching modalities. This observation underscores the diverse experiences and preferences of students in adapting to new learning environments. It highlights the importance of considering specific circumstances and factors (such as technological connectivity, specially adapted material, teaching strategies, and evaluation strategies) when designing and implementing teaching methodologies.

In the long term, the analysis revealed a generalised improvement in satisfaction levels across all questions, despite the disruptions caused by the pandemic. When comparing the co-located pre-COVID period with the co-located post-COVID period, the latter demonstrates higher satisfaction levels and less variability (i.e., more agreement in the ratings across students) for all questions except for SBJ (where the average remains almost at the same level but with a reduced standard deviation). This indicates an improvement in student satisfaction when compared to the pre-COVID period. These enhancements may be attributed to the lessons learned, adaptations made in teaching methodologies, improved teaching skills and course delivery during the pandemic, as well as other factors related to student life that have not been covered by this study.

ANOVA and Tukey honestly significant difference tests confirmed subtle long-term trends in satisfaction through the teaching modalities. Although certain aspects, such as satisfaction with the teaching plan contents and competencies, showed no statistically significant differences across different periods, other areas experienced notable shifts. A notable enhancement in satisfaction from T6 to T12 across key areas such as plan contents PLN: ($p = 0.0022$), teaching methodologies MTD: ($p = 0.0014$) compared to T6 and

(p = 0.0114) compared to T9, and overall teaching satisfaction TEA: (p ≤ 0.0016) was observed. This indicates some degree of relation between the end of the more acute phases of the pandemic and improved satisfaction, perhaps due to a return to more traditional teaching methods or the refinement of online teaching practices that were rapidly developed during the pandemic.

Aside from overall satisfaction, the study also found quantitative evidence of a decrease in satisfaction with the perceived workload for the ERT academic trimester. This was measured not only by a decrease in the average but also by a considerable rise in the overall variance, although it returned to near-normal (pre-COVID) values in the following academic trimesters.

Both co-located learning modalities (pre- and post-) were assessed as a more consistent experience for learners. The standard deviation of the responses for all questions and the IQR were reported to be higher for the ERT online period, signifying greater variability in students' responses during this time. This observation may be attributed to students' diverse experiences while adapting to the sudden transition to online learning, which may be connected to the diversity resulting from the initial improvisations done by educators in the change of teaching modality and differences in students' lifestyles.

Limitations and future work

First, this analysis is limited to the institutional satisfaction survey applied currently in a single HEI and limited to undergraduate programmes to control the complexity of the analysis. Second, the study is exposed to the typical limitations of research based on self-reported data; for the specific case of satisfaction surveys in education, assumptions about the honesty and good judgement of the respondents always are made; however, as stated by Elliott and Shin (2002), surveys are a commonly accepted and widespread tool for measuring some indicators of the quality of the educational service. Third, only the quantitative data related to the six-question survey was assessed in this stage of the research, the use of qualitative data could help to contrast and fine-tune the results. Finally, the study has not considered the effects of student lifestyles and the impact of the pandemic on them. For example, it is unclear if coming back to the co-located modality and to the usual academic dynamics (study patterns, social life, peer collaboration) might have been appreciated even more than in the past by the student community. Further research is required to understand the impact of this potential factor.

Regarding further research on the impact of teaching modalities on students' satisfaction, there is a current interest in diving deep into those learning design configurations that are to some extent related and affected by these changes in the teaching modalities, this could help to get better insights of their impact in the satisfaction indicators. Also, satisfaction is just one indicator among the ocean of student variables. In the scope of the institutional level, the relationship between satisfaction and student performance (grades, permanence time, contributions) and the facets of the learning designs implemented by the educators (with the support of their institutions) is still a sandbox of open questions that should be addressed.

Author contributions

Ariel Ortiz-Beltrán: Conceptualisation, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review and editing; **Davinia Hernández-Leo**: Funding Acquisition, Coordination, Conceptualisation, Investigation, Supervision, Writing – review and editing; **Ishari Amarasinghe**: Conceptualisation, Investigation, Writing – review and editing.

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